HOUSE OF COMMONS

Fourth Report from the

ENVIRONMENT COMMITTEE

Session 1983–84

ACID RAIN

Volume II

Minutes of Evidence

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The Environment Committee is appointed under SO No 99 to examine the expenditure, administration and policy of the Department of Environment and associated public bodies, and similar matters within the responsibilities of the Secretary of State for Northern Ireland.

The committee consists of a maximum of eleven members, of whom the quorum is three.

The committee has the power:—

(*a*) to send for persons, papers and records, to sit notwithstanding any adjournment of the House, to adjourn from place to place, and to report from time to time;

(*b*) to appoint specialist advisers either to supply information which is not readily available or to elucidate matters of complexity within the committee's order of reference;

(*c*) to communicate to any other such committee its evidence and any other documents relating to matters of common interest; and

(*d*) to meet concurrently with any other such committee for the purposes of deliberating, taking evidence, or considering draft reports.

Unless the House otherwise orders, all Members nominated to the committee continue to be members of the committee for the remainder of the Parliament.

FRIDAY 9 DECEMBER 1983

The following were nominated as members of the Committee: Mr Richard Alexander, Mr David Alton, Mr Sydney Chapman, Sir Reginald Eyre, Mr Reginald Freeson, Mr Robert B. Jones, Mr Norman Miscampbell, Mr Allan Roberts, Sir Hugh Rossi, Mr Chris Smith and Mr John Mark Taylor.

Sir Hugh Rossi was elected Chairman 15 December 1983.

FRIDAY 27 JULY 1984

Sir Reginald Eyre discharged; Mr Julian Critchley added.

The cost of printing and publishing this volume is estimated by Her Majesty's Stationery Office at £6,972

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MINUTES OF EVIDENCE TAKEN BEFORE THE ENVIRONMENT COMMITTEE

MONDAY 21 MAY 1984

Members present:

Sir Hugh Rossi, in the Chair

Mr Richard Alexander
Mr David Alton
Mr Sydney Chapman
Mr Reg Freeson
Mr Norman Miscampbell
Mr Allan Roberts
Mr Chris Smith

A LETTER—FROM THE CHAIRMAN OF THE ENVIRONMENT COMMITTEE TO THE CHAIRMAN CENTRAL ELECTRICITY GENERATING BOARD

ACID RAIN

The Environment Committee has begun an inquiry into acid rain, with the following terms of reference:

(i) To examine available evidence and current research on the emission, distribution and deposition of acidity in precipitation.

(ii) To examine the environmental effects of acid rain.

(iii) To examine the levels of and mechanisms for setting emission control standards in the light of evidence on the effects of acid rain.

(iv) To examine control emission technology, its cost, and any effect it would have in reducing any environmental damage attributable to acid rain.

I write to invite the Board to submit written evidence on

1. The factual evidence available to it in determining the level and effects of emissions.
2. Relevant pollution legislation including European
3. An assessment of research being done by the CEGB in this field
4. An assessment of emission control technology.

As you see, the Committee are seeking broad-ranging evidence. No decision on oral evidence has yet been taken, but I am sure the Committee will in due course wish to take evidence from you. Arrangements are in hand for the Committee to make a visit to the CEGB's research laboratories at Leatherhead, but no firm date has yet been agreed by the Committee.

The paper should be sent to the Clerk to the Committee in the Committee Office, and should reach him by 13 April.

7 March 1984

The cost of printing and publishing these Minutes of Evidence is estimated by Her Majesty's Stationery Office at £3,000.

LETTER FROM THE CENTRAL ELECTRICITY GENERATING BOARD

ACID RAIN

The Generating Board welcomes the invitation by the Select Committee to submit evidence on acid rain as requested in Sir Hugh Rossi's letter of 7 March 1984* to Sir Walter Marshall. We note in particular the Select Committee's request for evidence on:

1. The factual evidence available to the Board in determining the level and effects of emissions.

2. Relevant pollution legislation including European.

3. An assessment of research being done by CEGB in this field.

4. An assessment of emission control technology.

We thought it would be helpful to the Committee if our response on these subjects were given in the context of a general statement of the Board's policy and objectives in its approach to the problem of acid rain and of the work it is doing to resolve the many outstanding uncertainties, both on the causes and effects of acid rain and on the best measures for their control. The enclosed memorandum, therefore, sets out this general statement; the Annexes are addressed more specifically to the questions you have raised.

In respect of relevant overseas legislation, Annex 3 to our memorandum considers primarily the current position in the European Community as this is likely to be of most relevance to the UK; while the US scene is somewhat complex, the Committee will, no doubt, be aware of the recent decision by President Reagan not to institute new controls on SO_2 and other emissions at present but to propose increases in funding for further research into acid rain and emission control technology.

G. H. Hadley
Secretary
11 April 1984

MEMORANDUM BY THE CENTRAL ELECTRICITY GENERATING BOARD

ACID RAIN

General Policy and Objectives

1. In discharging its statutory obligations under the Electricity Acts and other legislation, the Board must not only have a proper understanding of the implications of its activities for the environment and public health, it must also ensure that whatever it does to protect the environment is actually effective. The issue of acid rain falls squarely within this general obligation to produce electricity economically but with due regard for the environment. Therefore:

—where there is genuine environmental damage,
—if it is due to acid rain,
—if reducing CEGB emissions would be effective in correcting the damage,
—if this would be the most cost effective approach,

then the Board would wish to take whatever action was necessary.

2. Recent scientific debate demonstrates that on no one of these aspects is there a clear scientific consensus. In many countries, including those stated to be most affected by acid precipitation, there is a wide spectrum of scientific view (if not outright controversy) on fundamental issues such as the extent to which acidification is due to natural processes or to mankind's exploitation or neglect of the environment; what agencies are responsible for the damage observed to certain tree species in parts of Germany; whether a reduction in sulphur dioxide emissions would lead to a corresponding reduction in rain acidity and

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* Printed page 1.

so on. The Board considers the major issues for resolution at the present time are:

1. What is the quantitative dependence of acid deposition in the UK and Europe on the relevant emissions–hydrocarbons and oxides of nitrogen as well as sulphur dioxide?
2. What is the contribution of acid deposition to ecosystem acidification? Is acidification reversible by reduction in acid deposition?
3. What is the effect of acid deposition, and the direct exposure to oxides of nitrogen and sulphur and other gaseous pollutants, on the growth, yield and health of crops and trees?

The CEGB has had to determine its policy on acid rain against the background of these and other uncertainties, and in the knowledge that a major programme of emission controls would be costly to the electricity consumer. The Board has, in fact, been undertaking and financing research to help resolve these issues for over a decade, a period in which SO_2 emissions in the UK actually fell by about 30%. Current Board activities include contributions to wider studies both on the nature and causes of acidification, and the costs and benefits of possible alternative corrective strategies. The Board is also mounting a substantial programme of emission control technology development, aimed at reducing the cost and energy penalties of emission control. A fuller description follows later in this memorandum.

Current Position and Further Research

4. There is now general agreement among international experts (such as those contributing to the studies under the UNECE Convention on Long Range Transboundary Air Pollution) that several of the problems which have been discussed under this general heading are not strictly related to acid rain as such. The potential effects of air pollutants on human health, on growing crops and on the corrosion of materials are seen as a consequence of high local concentrations of primary pollutants—sulphur and nitrogen oxides or ozone—and not materially related to the subsequent transformation of these pollutants into acid species affecting the quality of rain. In general, the causes of, and cures for, this type of local pollution are well known and do not call for the universal reductions of emissions from all sources. In particular, the contributions from distant sources in these cases will be very small and limitation of such sources will bring little or no relief to the areas actually affected.

5. The position is far less clear in the case of acidification of lakes and its consequences to fish life and on the causes of forest die-back in Germany. These are areas on which effort needs to be concentrated and where the Board's own research studies are directed; both in-house research and by means of sponsored external studies, such as those being undertaken by the Royal Society and the Norwegian and Swedish Academies with the aid of CEGB and NCB funds. A more detailed account of the present scientific position in these areas of concern is contained in Annex 1*, which is a report prepared for the Electricity Supply Research Council and presented to them in November 1983. It illustrates the lack of scientific consensus mentioned above. This report is relevant to Question 1 in Sir Hugh Rossi's letter of 7 March.

Emission Control Technology

6. A summary of the Board's action programme in this area, including a review of emission control technologies, has recently been prepared in response to the publication of the Tenth Report of the Royal Commission on Environmental Pollution and to their specific recommendations relating to the acid rain issue (paragraph 5.96 of the Tenth Report). The summary and review is attached as Annex 2, as relevant to Questions 3 and 4 in the 7 March letter.

7. The main purpose of this programme of work is to put the Board in a position to be able to introduce as quickly as possible the most cost-effective measures to respond to

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* Annex 1 not printed.

any perceived need which may, as scientific understanding improves, arise from the logic set out in paragraph 1 of this memorandum. In addition, the Board must be able to make a similarly effective response to new regulations introduced even if such regulations are, in the Board's view, unsoundly based. In such circumstances (amplified in the following paragraphs) the Board would wish the necessary emission limitations to be achieved at minimum cost to the electricity consumer. We should, however, make clear that our present view is that there is a high risk that heavy expenditure on new controls will not prove to be an effective correction to the environmental damage attributed to acid rain.

The Current UK Position on Control

8. Under Section 7 of the Alkali etc. Works Regulation Act 1906 (as incorporated in the Health and Safety at Work Act 1974), the CEGB is required to use '. . . the best practicable means for preventing the escape of noxious or offensive gases by the exit flue of any apparatus used in any process carried on in the work and for preventing the discharge, whether directly or indirectly, of such gases into the atmosphere and for rendering such gases where discharged, harmless and inoffensive . . .". Sulphur dioxide is included in the list of "noxious and offensive gases" over which the Inspectorate have jurisdiction.

9. As drafted, this requirement includes no reference to need or to costs. It implies only that if a control measure is deemed to be "practicable", then it must be adopted and that the primary emphasis is on a limitation of emissions at source. It is well known, however, that the Air Pollution Inspectorate do consider the financial impact of control measures in defining what is, or is not, "practicable". What is less clear is the extent to which a demonstrable need must be proven before they insist on the adoption of otherwise practicable control measures. The Inspectorate is quite likely to take a precautionary attitude where the cost/benefit ratio of a proposed control measure is still obscure but where the costs, in its estimation, do not represent an undue financial burden on the works concerned.

10. Apart from possible requirements on new plant that must be agreed with the Air Pollution Inspectorate, all fossil fuelled stations built since the formation of the CEGB are subject to the condition (in their statutory consent under the Electric Lighting Act 1909) that space must be left for the later provision of sulphur removal equipment should the Secretary of State require this to be fitted. In over thirty years, this condition has never been invoked.

11. In summary, either the Secretary of State or the Air Pollution Inspectorate have the power to require the provision of sulphur removal equipment under existing legislation. In the case of the Secretary of State at least, this could extend to retrofit applications.

Other Legislation

12. Whilst the Generating Board attempts to keep informed of legislative developments for pollution control in other countries, it does not maintain fully up-to-date records of such statutes, nor would it consider itself an appropriate authority to make detailed comparisons or to comment on the legal implications. However, we believe the Select Committee will expect the Generating Board to comment instead in a more general way on the nature of the different legislative approaches that can be adopted, and specifically on current legislative proposals within the European Community and how these might affect the Board.

13. Within Europe, only the Federal Republic of Germany has so far adopted national legislation which imposes quantified limitations on the emissions of sulphur and nitrogen oxides, etc. from power stations and other large combustion plant. Some other countries may tend towards similar legislation in the future, but at present the majority of nations, including the UK, do not impose such controls. In Scandinavia and elsewhere, the first approach has been to place limits on the allowable sulphur contents of fuels used for a wide variety of purposes; particularly on heavy fuel oil used mainly by power plants and heavy industry and on the lighter fuels used generally in industry, commerce and transporta-

tion. In Denmark, for instance, which has recently produced a plan to cut sulphur dioxide emissions by 30 per cent over the next decade, the primary contribution will come from such limitations on fuel quality and only a minor part will result from the use of emission control devices (flue gas desulphurisation) fitted in power stations.

14. Whilst there are thus no measures to control the total emission of pollutants in Europe, virtually all countries have adopted measures for preventing high local concentrations of these pollutants in the ambient air; namely by the use of tall chimneys to ensure adequate dispersion. This requirement will remain even if other limitations on emissions are exercised.

15. The differences in national approach to emission control reflect, to some extent, their past experience with air pollution problems. In the United Kingdom, the major concern in the past was the episodes of excessive pollution that occurred in London and other cities. It has long been understood that these resulted from small low level sources of emission, mainly domestic and commercial buildings, and were not principally the result of industrial activity. This led to the recognition that there were several "air pollution problems" and that different legislative measures were required to deal with each one. Without this background of experience, some other countries have concentrated instead on controlling major emission sources of which power plants are usually the main component. Such controls would be appropriate where the principal concern was long distance effects, perhaps in other countries, but would provide no guaranteed alleviation of local urban air pollution. In this context, it is important to note the growing number of air pollution effects which are recognised as being of a local nature rather than the effect of long distance transport of pollutants from remote sources.

16. Two proposals for Community legislation have recently been drafted by the European Commission and one has been adopted after modification by the Council of Ministers, i.e. the Directive COM(83)173 on The Combating of Air Pollution from Industrial Plants. The second Draft Directive COM(83)704 on The Limitation of Emissions for Large Combustion Plant has still to be discussed and adopted. Both of these measures closely follow the German pattern of legislation in:

(*a*) concentrating on large industrial sources of pollution,

and

(*b*) in seeking to impose specific limits on the allowable emissions to air.

17. The Board has examined both measures in detail. In addition, the Board has studied the economic arguments advanced by the Commission in the preamble to Directive COM(83)704 and its accompanying explanatory memorandum. In our view, the claim made by the Commission that the financial benefits of controlling emissions would outweigh the costs of imposing the controls, has not been substantiated. A closer look at the figures suggests that the maximum estimates of benefit will still fall well short of the minimum cost of applying the emission controls. The Board's commentary on the Directives and its analysis of the economic arguments is attached as Annex 3, as relevant to Question 2 of the 7 March letter.

Summary

18. The Board have, of course, always recognised the value of an international approach. We believe our programme of research and emission control technology development accords fully with the spirit of the UNECE Convention of 1979 in seeking to ensure that whatever is done will be ecologically effective and, as far as possible, cost-effective. The Commission's present proposals, and in particular COM(83)704, are not based on a thorough examination of costs and benefits and are, in the Board's view, premature and depart from this principle. If action is to be taken, and is justified, it would be much more likely to follow from the adoption of long-term national targets covering emissions from all sources, allowing for periodic revision in either direction in the light of scientific and technical progress. An approach by the Commission on this basis would align EEC and UNECE policies.

19. In parallel, and offering hope of lower costs and an earlier impact, the CEGB believe that strategies of resource and ecosystem management should be developed. Considerable success has been achieved in Sweden in liming lakes. With appropriate developments and precautions, there is no reason to believe that the Swedish success cannot be translated into other locations experiencing acidification, and extended to treatment of ground acid wastes. In this context, we would draw the Committee's attention to a recently announced project, which will commence this summer, to explore techniques of land treatment and management to improve the water quality in Loch Fleet, Galloway. The project is being funded by the two Scottish Electricity Boards, the NCB and the CEGB, and has been welcomed by the Forestry Commission, the Solway River Purification Board and the Scottish Development Department. It is intended that it should lead to the development of practical and economic measures to counter the effects of acidification.

CEGB ACTION PROGRAMME ON EMISSIONS

In their Tenth Report, the Royal Commission on Environmental Pollution gave consideration to the problem of acid deposition. They drew attention to many of the uncertainties in regard to the scientific basis for the current concerns (paras 5.84 to 5.87) and also to the doubts about the best measures to adopt in order to reduce and prevent ecological damage from this cause (paras 5.90 to 5.95).

The Royal Commission recommended (para 5.96) that "high priority should be given to research on acid deposition, in particular on the causes and effects, on the interactions with other pollutants, and on remedial action". Recognising the United Kingdom's obligation under the UNECE Convention and the technical and economic advantages of a carefully phased programme over a reasonable timescale, the Royal Commission further recommended that the CEGB "should introduce on a pilot basis, over the next five years, certain of the sulphur abatement options that are already available" (para 5.96).

The CEGB believes that its recently expanded action programme on the effects of its emissions and on emission control technology, both in house and in collaboration with other bodies, meets the spirit and intent of the Commission's recommendations. It is the Board's intention to give greater publicity to its action programme. In the meantime the present summary may be helpful to the Select Committee.

The Board is at one with the Commission on the importance of fundamental scientific studies on effects to establish whether or not subsequent expenditure on control measures will be effective in solving the perceived problems. The current state of scientific knowledge leads us to the view that there is a high risk that heavy expenditure on emission control systems will still not prove to be an effective solution.

Nevertheless if improved understanding or international agreements require further control of SO_2, NO_x or dust emissions from new plant or SO_2 from existing plant, the action programme set out in Annexe 1 will prepare the Board and its suppliers for any reasonable requirements. The extent of possible reduction of NO_x or dust from existing plant must await the outcome of the programme.

The attached table lists the components of the current action programme, both on the effects of emissions of SO_2, NO_x and dust on the environment and on the development of control measures for these pollutants. An indication of the cost and timescale of each project is given where they involve external contracts, joint studies or large purpose-built rigs. Where no cost is indicated, the work is currently being conducted in-house under the CEGB budget for research and engineering development. A fuller description of the emission control technologies available, or under development, is appended, including an indication of the likely costs of application.

It must be pointed out, however, that any requirement to retrofit new SO_2 controls on a substantial proportion of our existing modern combustion plant would take a decade or more to plan and execute. It would be nearer 20 years before its effectiveness in solving problems of environmental acidification could be determined.

In the meantime there is an urgent need to seek more rapid solutions by means of measures applied locally to the areas affected by acidification, whether naturally or by acid deposition. We believe this also falls within the term "remedial actions" recommended by the Royal Commission. The Board is therefore mounting a project in conjunction with the SSEB, the NCB and several research institutes, to restore fish to Loch Fleet in Galloway by scientifically based treatment of its catchment. The project has been welcomed by the authorities responsible for water in this area.

The Board believes that its programme of action on emissions will contribute significantly to effective and cost-effective solutions to the difficult problem of environmental acidification and to the sound understanding which is a pre-requisite for effectiveness. The span of the programme puts the Board in a state of technological preparedness for any reasonable requirements in the short, medium or long term. It appears to be entirely in the spirit of the Royal Commission recommendations.

CEGB ACTION PROGRAMME ON EMISSIONS OF SO_2, NO_x AND DUST

As at 19 March 1984

	Useful results available	*Cost (per cent CEGB)*
BASIS FOR EFECTIVE ACTION		
1. Research on: —transport in the atmosphere —contribution to acid deposition —effects of SO_2, NO_x, O_3 and acid deposition on plants, trees, soil, water —effects of acid water on fish —contribution to corrosion of materials —health effects	Ongoing	£1.5m p.a.
2. Royal Society Fund: —to determine the causes and effects of surface water acidification	1986–1988	£5m (50 per cent)
CONTROL TECHNOLOGY		
1. FLUE GAS DESULPHURISATION		
1.1. Engineering Assessment of Wellman Lord process —commercially available	Complete	£85K
1.2. Engineering Assessment of Limestone/Gypsum process —commercially available	1985	£45K
1.3. Pilot Installation of HCl Prescrubber for 1.1 or 1.2 —necessary for UK coals	1985	£200K
1.4. Comparative study of FGD and coal washing including "enriched" streams to FGD	1985	(shared with NCB)
1.5. Assessment of "once-through" sea-water washing process	Ongoing	—
2. Coal Preparation for Sulphur Reduction		
2.1. Joint study of potential for CEGB	1985	(shared with NCB)
2.2. Rig trial of high gradient magnetic separation	1986	£150K
2.3. Pilot combustion trials of cleaned coal—Ferrybridge C 1985 with NCB	1985	£6m
2.4. Evaluation of advanced techniques	Ongoing	—

	Useful results available	*Cost (per cent CEGB)*
3. Coal Water Mixtures		
—as a low sulphur replacement for oil		
3.1. Assessment of potential for UK	Ongoing	—
3.2. Laboratory scale preparation	Ongoing	—
3.3. Laboratory scale combustion trials	Late '84	—
3.4. Planning of station trial of commercial CWM	Open	£m several
4. PFBC Combined Cycles		
—as a high efficiency system for the 1990's with built in sulphur retention		
4.1. Tripartite outline design study with British contractors	1985	£378K (33 per cent)
4.2. Practical development at Grimethorpe Phase A, three years	1986–87	£25m (33 per cent) (with NCB and D.En.)
5. Gasification Combined Cycles		
—as a potentially high efficiency system for 2000 and beyond with built-in sulphur retention		
5.1. Design study with BGC, NCB, DEn and British contractors	1985–86	—
6. Low NO_x Burners		
6.1. Laboratory basis	Ongoing	—
6.2. Low NO_x burner development with British manufacturers	1985	£600K
6.3. Station trial of low NO_x burners	1986	£2m
6.4. Station trial of rich fireball low NO_x configuration	1987?	£2m
7. Direct Injection of Limestone		
7.1. Assessment of potential and costs with HMIAPI, DEn, DoE	Complete	—
8. Dust		
8.1. Large scale precipitator development rig at CERL	Ongoing	£650K
REMEDIAL ACTION		
1. Restoration of fish in Scottish Loch	1987–1989	£600K

EMISSION CONTROL TECHNOLOGY

Control of nitrogen oxide emissions (NO_x) can be achieved either by modification of the combustion process or by reduction in the flue gas (denitrification).

Control of sulphur oxide emissions (SO_x) can be achieved before, during or after combustion.

NO_x CONTROL

Modification of the Combustion Process:

In this approach mixing of air and fuel is delayed, which favours the suppression of nitrogen oxides. Depending upon the boiler and the sophistication of the technology applied, reductions of the order of 30 to 50 per cent can be achieved. The principal uncertainties are the possibilities of significantly increased boiler tube failure (already costing the Board £40m*), which grows with increased level of abatement, reduction in boiler efficiency (one-half per cent would cost £15m pa totalled across all high merit units) and deterioration of precipitator performance. Because of the high chlorine content of UK coals and the relatively tight and differing design of the CEGB's boilers, foreign experience will be of limited value. Trials on UK plant are necessary and are being planned. Development of a low NO_x burner suitable for our wall fired boilers is being undertaken with Board funding by a UK manufacturer. Bearing in mind the limitations on burner size and geometry set by existing plant, abatement of the order of 30 per cent would seem a reasonable target for retrofitting in the UK situation, subject to the requirement of maintaining a satisfactory boiler life. The cost of retrofit is between £1.2m and £1.6m for 500 MW units depending upon boiler type and about £2m for 660 MW units. This takes no account of possible modification of mills in the event of needing to change the fineness of grind.

Flue Gas Denitrification:

In this approach the flue gases are reacted over a catalyst with ammonia to remove nitrogen oxides. Very high levels of abatement are possible by this technology, in excess of 80 per cent has been claimed. However, there are major uncertainties concerning the life of the catalyst and the feasibility of its regeneration. These make it impossible to cost with any accuracy. In general terms, however, it appears that the capital cost would be between five and 10 times that of burner modifications for NO_x reduction—the latter would, in any case, be a pre-requisite in order to minimise total costs. Recurrent costs would hinge critically upon catalyst life, assuming a two year life in accord with German and US estimates, these would be of the order of £5m/a for a 500 MW unit.

SO_x CONTROL

Before Combustion

Coal cleaning: The potential for coal cleaning as a means of sulphur emissions abatement is currently being studied with NCB. Indications so far are that extending washing to all the CEGB's supplies would reduce overall SO_x emissions by about eight per cent. Economic assessments which are still in progress show that the first two per cent can be removed more cheaply than by FGD, data on further tranches will become available later in the year. The evaluation incorporates estimates of benefit from burning lower ash fuels in the Board's boilers. A plant trial is being planned to firm up on these estimates and confirm that there are no operational problems when burning very low ash fuel.

Gasification: A joint study by D.En/CEGB/NCB/BGC is investigating the possibility of using the BGC Lurgi Slagging Gasifier in a combined cycle for power generation both with and without shared use with BGC for SNG production. Design contracts are to be placed with plant manufacturers. Indications from preliminary studies are that the system will only become competitive if the further developments of gas turbines that are envisaged by manufacturers over the next decade are, indeed, carried through.

During Combustion

Direct lime/limestone injection: In this process a sorbent (lime or limestone) is injected into the furnace. Studies made on pilot and full-scale plant show that for this process to be effective the boiler must have been modified to function in a low NO_x mode, ie with staged combustion. An outline engineering evaluation for a 500 MW plant using limestone concluded that a maximum of about 35 per cent reduction in SO_2 could be achieved at a capital cost of £78m and operational costs of £13.5 m/a. Both capital and revenue costs are significantly higher per tonne of sulphur abated than with flue gas desulphurisation. Moreover the limestone needed would increase the ash burden in the system by over 50 per cent with a large and adverse change of ash chemistry—it has not been possible to assess the deleterious impact on boiler availability that such a significant change would have.

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* All costs as at March 1983.

Pressurised fluidised bed combustion: This technology, exemplified by the Grimethorpe pilot scale plant, is still at the development stage and is the subject of a design study funded by D.En/CEGB/NCB. By use of dolomite, and possibly limestone, in a pressurised fluidised bed (PFB) it is possible to remove about 90 per cent of the sulphur. Incorporation of the PFB in a combined cycle permits high power generation efficiency to be maintained with high sulphur capture. Preliminary studies, carried out as a prelude to placing design contracts with manufacturers, show generation efficiencies of approximately 40 per cent to be feasible and overall costs that are lower than conventional plant fitted with FGD subject, of course, to satisfactory development.

After Combustion (FGD)

Flue gas desulphurisation (FGD) is achieved by contacting flue gas with wet or dry alkali which absorbs the SO_2. A wide range of different processes have been developed. At present only the wet processes have been operated adequately at a scale which makes direct translation to the CEGB operation credible.

Four wet processes were considered as being available commercially at the necessary scale; they are all capable of about 90 per cent desulphurisation. However, since one produces a slurry of calcium sulphate and sulphite that would pose substantial disposal problems, attention was directed to the other three, namely, Wellman Lord, Limestone Gypsum and Sea water Washing. Clearly, the latter would only be applicable to coastal coal fired stations. Currently a chloride prescrubber is being developed as a necessary precursor to being able to specify an FGD plant for UK conditions.

The capital cost of providing an FGD process at a new 2000 MW power station would vary between £60m and £125m depending on the system selected (the lower figure applying only to sea-water washing). The increase in the total electricity generation cost (revenue costs plus capital repayment), would be between £24m and £30m per annum; these figures allowing also for the cost of replacing lost output from the station due to the consumption of electricity by the FGD process. In the case of existing plants, retro-fitting an FGD process would be more expensive; up to £160m capital for a 2000 MW station. The increase in total generating cost would also be higher, at up to £35m per annum.

The cost of FGD per tonne of sulphur abated will vary between about £440 per tonne and £740 per tonne, depending on the process adopted; the average being about £550 per tonne.

COMMENTS ON EUROPEAN COMMUNITY DIRECTIVES CONCERNING EMISSIONS TO AIR

Two recent legislative proposals by the Commission concern emissions of air pollutants from large industrial plant including power stations. The first Directive, on combating of Air Pollution from Industrial Plants (COM(83)173), has been adopted after modification by the Council of Ministers. The second Directive, on The Limitation of Emissions of Pollutants into the Air from Large Combustion Plants (COM(83)704), is still under discussion by the Council.

COM(83)173

This Directive seeks to harmonise the procedures for authorising air pollution control measures on new industrial plants. It also establishes the principle that the Council, acting on a proposal from the Commission, can fix emission limit values on a Community wide basis.

In the form of wording finally adopted, this Directive is welcomed by the Generating Board. The measures for harmonisation of procedures appear to require very little change to existing UK legislative procedures which are adequate to ensure proper control of industrial emissions. Whilst the wording of Article 8, on the fixing of emission limit values, originally gave cause for concern, the final text makes very adequate reference to the need to have regard to the costs of the technological measures adopted and to the need to take account of the nature, quantities and harmfulness of the emissions concerned. The Board is also pleased to note that any emission limits fixed in response to this Article now require the unanimous approval of the Member States.

Two shortcomings of this Directive still remain:

1. The preamble to the Directive invokes Article 100 of the Treaty, which is designed to remove unequal conditions of competition. However, the proposals would affect only fossil-fired electricity generation. Within Member States the proportion of electricity derived from coal and oil varies between 37.8 per cent (France) and 100 per cent (Denmark), the average for the ten Member States being 72.5 per cent. The effect of the proposals will therefore be to impose different additional costs of electricity generation on to different Member States. The proposals will also in general act to dissuade operators from adopting coal as a basic fuel in direct contradiction of Commission initiatives designed to increase the use of coal.

2. Experience acquired over many years of development and application of air pollution control measures in the UK has shown that the determination of soundly based criteria for human, animal and ecological health and well-being is an essential first step. Acceptable air quality standards for pollutants can then be developed ie allowable concentrations of the pollutants in the ambient air. Finally any emission limit values essential for the achievement of the air quality values can be set down, ie the allowable rates of emission from individual works or chimneys. For some pollutants (notably sulphur dioxide (SO_2)) the Commission has moved along this course, adopting World Health Organisation criteria and setting air quality values. For other pollutants (eg nitrogen oxides (NO_x)) the process is still under way with current discussion centering on air quality values. For the majority of the pollutants named in the Directive the process has hardly begun. The Commission should be urged to follow a more rigorous approach, which would establish the most cost-effective way of ensuring that the criteria for human, animal and ecological health are met.

COM(83)704

This proposed Directive sets out numerical limit values for emissions of sulphur dioxide, nitrogen oxides and particulate matter from new large combustion plant (greater than 50 MW thermal rating). It also seeks on a collective basis a substantial percentage reduction in the corresponding emissions from existing plant based on 1980 emission levels.

The Board wishes to draw to the Select Committee's attention a number of matters, both in general and in detail, concerning this Draft Directive;

3. Much has already been achieved within the Community on the control of air pollution and the reduction of emissions. A recent review by UNECE of strategies and policies for the abatement of air pollution caused by sulphur compounds shows a marked reduction in most Member States of emission of SO_2 between 1978 and 1985. Emission of the same pollutant from the UK now stands at around 4.0 million tonnes per year having fallen from around 6.1 million tonnes in 1970, a reduction of 34 per cent in little over ten years; all achieved without significant recourse to uniform emission limitations. Within the CEGB the continuing search for more efficient electricity generation has brought about a 20 per cent reduction in the amount of SO_2 emitted per unit of electricity generated since the industry was nationalised. These achievements should be taken into account when setting further targets for reduction of emissions.

4. Throughout the Community the two problems of air pollution requiring most serious attention are the possible effects on materials (including cultural monuments) and on forests. In the former case a recent report from a Working Group of Experts set up under the UNECE Convention on Long Range Transboundary Pollution has concluded that the corrosive action of sulphur compounds is usually restricted to an area close to the source. In the latter case a recent meeting of the FAO/ECE Working Group on the Impact of

Air Pollution on Forests considered that there was evidence of direct action of air pollutants acting together with normal stress factors (such as disease and drought) to produce observed damage to forests. High concentrations of these pollutants occur relatively close to large sources; acid rain or international transfrontier pollution are unlikely to be a significant factor. In Germany the most recent work has shown that ozone acting alone or in conjunction with drought may be the most probable cause of the damage observed in forests. Remedies can be found for both of these major European air pollution problems in control methods applied by Member States individually or perhaps in some cases through bilateral discussions between adjacent States.

5. Insofar as it relies on the 1982–86 Action Programme of the European Communities on the Environment, COM(83)704 suggests some ignorance of the role of industrial emissions as part of the total problem of air pollution, and particularly of the role of the large stationary sources with tall stacks. The study carried out for the Commission by Environmental Resources Ltd. (ERL) states (p 36, paragraph 3.6) "It is generally acknowledged that emission height makes very small difference to long range pollution transport under Western European conditions averaged over the year". These matters were the subject of evidence by CEGB to the House of Lords Select Committee on the European Communities and were discussed in the 16th Report. As already noted, in cases where the effect of pollution occurs local to the source, rather than at distances involving transboundary considerations, the need for Community legislation is not apparent.

6. In relation to costs and benefits in COM(83)704, the Commission, in the Explanatory Memorandum, appears to be misquoting the figures produced for them in the report by ERL, in both minimising the costs of controls and exaggerating the benefits they will produce. It may be noted that ERL themselves estimated that the cost of controls on the scale envisaged by the Directive would be \$4.6–6.7 thousand million pa for the whole Community whereas the total benefits were only between \$0.5–3.5 thousand million pa. The Board places great importance on the need to get these economic arguments in correct perspective. A more detailed analysis of the likely costs and benefits of the emission controls proposed in the Directive is given in the Appendix.

7. In the context of the Geneva Convention on Long Range Transboundary Air Pollution (which the Commission cites in the preambles to the Draft Directive), the proposals by the Commission appear inconsistent. At the UNECE Executive Board Meeting in Geneva, the EEC and its Member States were largely instrumental in opposing the Nordic proposal for a 30 per cent cut in SO_2 emissions throughout Europe and in substituting a vaguer wording without a numerical target. Now the Commission itself is proposing a target reduction twice as great and with large percentage cuts in NO_x and particulate emission as well. The inclusion of controls on particulate emission is also inconsistent with a Directive aimed principally at acid rain, as cited in the preamble. Much of the dust from coal burning, for instance, is alkaline and will tend to neutralise the acidity produced by SO_2 and NO_x. In addition, there is no claim anywhere in the Directive or accompanying documents that the dust from large combustion plants is a hazard to health.

8. The proposals to cut back emissions from existing plants by 1995 would undoubtedly require a major and costly engineering development and construction programme. If implemented, the target reduction of 60 per cent for sulphur dioxide would certainly imply retrofit of Flue Gas Desulphurisation to up to a dozen of our largest plants. The 40 per cent reduction in No_x emission would be more problematical; at this stage we do not know whether it is possible to retrofit low NO_x burners to the majority of our boilers.

PROPOSED DIRECTIVE ON THE LIMITATION OF EMISSIONS FROM LARGE COMBUSTION PLANT (COM(83)704)—BENEFITS AND COSTS

INTRODUCTION

The proposed Directive (COM(83)704) lays down stringent emission limitations on SO_2, NO_x and dust. In justification the accompanying explanatory memorandum projects the benefits to be

	US \$ per year
1. Corrosion of buildings and materials	$0.5–2.7 \times 10^9$
2. Loss of agricultural yield	$0.9–1.1 \times 10^9$
3. Loss of forest yield	0.3×10^9
4. Damage to public health	0.02×10^9
5. Loss of revenue from tourism, fishing, etc.	0.01×10^9
Total	$1.4–4.2 \times 10^9$

At the same time the memorandum puts the cost of implementation of the Directive at $\$1.15 \times 10^9$ per year.

CRITIQUE

1. The explanatory memorandum accompanying the Directive presents arguments in support of the proposals which are scientifically fallacious and demonstrate an alarming level of ignorance within the Commission about acid precipitation and air pollution in general. Little of the damage costs would be removed by the proposed measures. The Commission has underestimated the cost of these measures by a factor of five principally through neglect of the major cost of substantial retrofitting of flue gas desulphurisation. The cost of the proposed measures is probably an order of magnitude larger than the benefit that might be expected.

2. In many instances the remarks made in the Directive conflict with statements made in the report produced for the Commission by ERL*. The Commission singles out plant with tall stacks for action on the grounds that these spread pollutants over long distances. The fallacy of this is well known and well expressed by ERL.

> "It is generally acknowledged that emission height makes a relatively small difference to long range pollutant transport under Western European conditions averaged over the year".

Because of this the Directive fails to recognise that many of the potential damage costs can be assigned to local sources and that therefore the Directive, by attacking large combustion plant, would not address a considerable portion of the alleged damage.

3. According to the Directive the emission standards chosen are "justified by the conclusions of the Karlsruhe Conference held in September 1983 and the Stockholm Ministerial Conference held in June 1982 . . .". The source of these so-called "conclusions" is not stated and has not been traced. The justification for the introduction of more stringent controls on dust emissions is quite unclear. Nowhere is any connection with acid rain alleged nor are any damaging effects from current levels of dust emissions from tall stacks claimed.

4. The UNECE assessment of damage by air pollution to buildings and materials concluded that the origin of such damage is primarily local. In most towns and cities tall stacks will contribute 25 per cent or less to local SO_2 concentrations. The proposed measures would therefore be largely ineffective. The damage cost quoted by the Commission ($\$0.5–2.7 \times 10^9 y^1$) is derived from the UNECE estimate of all building damage due to sulphur compounds. Laying aside any criticism of this figure as a total, it is obviously far in excess of that portion attributable to large combustion plant.

5. On the damage to crops, the ERL report reflects the currently held scientific view that normal rural and probably urban concentrations of SO_2 are below the apparent thresholds for damage. The effect on soil acidity of acid rain is likely to be insignificant compared with the effects of eg fertilisers and the acidity of rain has not been shown to be detrimental to crops. The Commission's estimate of damage costs ($\$0.9–1.1 \times 10^9 y^{-1}$) is based on the arbitrary assumption that 40 per cent of agricultural and horticultural

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* Acid Rain—A Review of the Phenomenon in the EEC & Europe. Environmental Resources Limited (1983).

areas are affected by damaging levels of pollution and this results in a 10 per cent loss of yield. There is little justification for this and the knowledge on thresholds suggests that it is a gross overestimate. There may be a synergistic relationship between SO_2 and ozone but since high ozone levels are associated with urban pollutants, large combustion plant are likely to be small contributors to concentrations of SO_2 prevailing at the same time. The proposed measures will therefore have a minimal effect on any crop damage that might exist.

6. The analysis of forest damage prepared by the Swedish Ministry of Agriculture for the Stockholm Conference reported no clear evidence for either increased or decreased growth in sensitive areas and that previously reported damage had not been confirmed. In Germany, the ERL report supports the current view that ozone damage to needles in conjunction with drought is the most likely cause of the reported damage and that other factors such as climate, forest management and soil types have rendered the German forests particularly susceptible. Action on air pollution to allay this damage should therefore be aimed at ozone rather than large combustion plant. The damage costs given by the Commission ($\$0.3 \times 10^9 y^{-1}$) is based on the estimated current loss to German forests ($\$0.2 \times 10^9$) plus an allowance for a 10 per cent loss of yield from 20 per cent of other European forests, an arbitrary assumption. In view of the probable causes it is therefore unlikely that the measures proposed will have significant beneficial effects.

7. In its review for UNECE the WHO concluded that current levels of air pollution have no significant effect on mortality and morbidity. Therefore there would appear to be no basis for introducing control measures on health grounds. There is no documented evidence that adverse health effects have resulted from acid rain. The Directive draws attention to an estimate of the cost of damage to public health ($\$0.3\text{–}1.7 \times 10^9 y^{-1}$) drawn at random from a number of estimates made by OECD. This estimate relies on the now unsupported early work of Lave and Seskin which assumed a contentious dose-response relationship and direct proportionality between mortality and morbidity. This leads to a gross overestimate since, even if the dose response relationship is accepted, only a limited portion of health service care is remotely connected with air pollution. The Directive also quotes a cost ($\$0.2 \times 10^9 y^{-1}$) for water treatment for health needs. Even if acid precipitation does contribute to low pH of drinking water, it is not the only contributor and the cost of remedial measures by the usual techniques must be small compared with controlled emissions and would moreover cover any other cause of acidification.

8. The ERL report points out that probably no significant overall loss of revenue from tourism, due to acid rain, actually exists. However, the argument on this centres around the acidification of lakes by acid rain and here the circumstantial evidence against acid rain is stronger. There seems little doubt that acid precipitation has been partly responsible for the acidification of some lakes in southern Scandinavia in which the pH is observed to be sufficiently low to be explicable only in terms of strong mineral acid. However, no simple relationship exists between the amount of acid deposited and the fishery status of a lake. The benefit that might be derived from reducing emissions cannot be accurately stated but recent work suggests that a 50 per cent reduction in sulphur deposition might result in only five per cent of the affected lakes being able to support good populations of fish. The Commission's estimate of damage cost ($\$0.02 \times 10^9 y^{-1}$) is based on a notional hypothesis that half the estimated loss of Scandinavian fisheries might be recoverable as a result of emission controls. Estimates of the cost of liming are comparable with the estimated total fishery losses, but two orders of magnitude less than the cost of sulphur emission control costs.

9. The Commission estimates that 40,000 MW of new plant will need to be fitted with abatement measures at a cost of \$100 per kW. ERL quoted a cost of \$130–150 per kW, but this possible underestimate is insignificant in comparison with the fact that the Commission failed to include FGD retrofit costs. ERL estimated this at $\$2.7\text{–}3.6 \times 10^9 y^{-1}$ with an additional cost of $\$05. \times 10^9 y^{-1}$ for oil desulphurisation. For NO_x control costs, the Commission adopted the mean of the range estimated by ERL ($\$0.1\text{–}0.4 \times 10^9 y^{-1}$). Although the need for particulate control cannot be justified the Commission includes an estimate of $\$0.25 \times 10^9 y^{-1}$. If FGD retrofit and oil desulphurisation costs are added to the Commission figures then the total cost comes to $\$4\text{–}5 \times 10^9 y^{-1}$ which compares well with

the OECD estimate of $\$4.6\times10^9y^{-1}$ for a 37 per cent reduction in SO_2 (based on 1974 emissions). These total costs are an order of magnitude larger than the benefit which might be expected.

CONCLUSIONS

In short, costs are underestimated by about a factor of five. Benefits are overestimated by a substantial, but unquantifiable amount, mostly due to a misunderstanding of the causes of the alleged damages. Claims that the Directive will be cost-effective are manifestly unsound and no consideration is given to alternative, less costly and more assured countermeasures such as liming.

Examination of Witnesses

SIR WALTER MARSHALL, CBE, Chairman, DR P. F. CHESTER, Director, Technology, Planning and Research Division, MR A. J. CLARKE, Technology, Planning and Research Division, Central Electricity Generating Board, called in and examined.

Chairman

1. Good afternoon, Sir Walter. May I thank you and your colleagues for presenting the evidence that you have to us in writing. Some of us also recall the very interesting visit we paid to Leatherhead to see for ourselves the research work that is being carried out on the problems you are trying to beat. In connection with the memorandum that you have submitted to the Committee, there does not seem to be any reference to the quantity of SO_2 or NO_x that is emitted by your authority. Can you tell me why there are no figures at all?

(Sir *Walter Marshall.*) Yes, Mr Chairman, I am sure Dr Chester can tell you that immediately. I would like, first, however, to make a very brief statement, that I have come here with some diffidence because this is a subject I do not yet understand. It is a complicated subject and I have been Chairman of the CEGB so far not yet two years.

2. We will all struggle together then.

(Sir *Walter Marshall.*) Yes, indeed. I was driven between two irreconcilable objectives. I was keen to give you the opportunity of questioning me but desperately anxious you should actually question my colleagues. I have attempted to reconcile both of those by appearing and then, therefore, when you ask me a factual question like that, I am afraid I will always have to refer to my colleagues, and Dr Chester will now answer your question.

(Dr *Chester.*) If we are talking in terms of sulphur dioxide in millions of tonnes a year, in 1982 we think that the CEGB emitted about 2.4 m tonnes of sulphur dioxide as sulphur dioxide. With regard to nitrogen oxide emissions, we emit, the quantities here are subject to a wider margin of error but we think roughly 0.7 m tonnes, measured as NO_2, that is, weighed as NO_2, nitrogen dioxide, although, in fact, the chemical form in which we emit it is nitrogen oxide, nitric oxide.

3. How far back do your records go?

(Dr *Chester.*) The numbers I have with me go back to 1973 and I could give you those, if they would be of interest. We could, of course, go back earlier.

4. Perhaps you could let us have a note of those later because to take in figures will take up time unnecessarily, but can you tell us from the figures in front of you whether there is an appreciable increase or decline over the period in question in either of those two chemicals?

(Dr *Chester.*) Yes. In the case of SO_2 over the ten-year period to 1982 emissions of SO_2 have declined from about 2.7 to about 2.4 m tonnes, and the NO_2 figures probably from something a bit above 0.7 to something a bit below 0.7—not so marked.

Mr Smith

5. The figures which the DOE provided to us about overall SO_2 and NO_x emissions from various sources in Britain show that, globally speaking, our emissions as a country have declined in each case by something like 30 per cent over that ten-year period. By your own figures your emissions have declined by nowhere near as much as that overall reduction. Why is that?

(Dr *Chester.*) There are several reasons for that. Let us take SO_2, where it is clearer. There has been a switch in the pattern of coal burning in the country. If we go back 20 or 30 years clearly there was a lot of

[Mr Smith *Contd.*]

domestic use of coal. Electricity has taken a larger proportion of the coal burn (if I may put it that way) and natural gas, which contains no sulphur, has taken an increasing proportion of the domestic burn, so the CEGB and the Scottish Boards are in a sense carrying a larger proportion of the coal burn in converting it to electricity than the proportion of the country's coal burn in former years. The NO_x trends are not so clear and I think that that is a blend of a number of things, including transport and so on. I do not think there is such a clear answer with respect to nitrogen oxides.

Mr Freeson

6. We are speaking about the period from 1974 to 1983 approximately. We have just had the explanation given that the reason why there has been a disparity in the fall in production (if I may put it that way) of SO_2 between the two categories is because the domestic consumer has switched to natural gas and the like at a greater rate than has been the switch from coal to other forms of generation in the CEGB, but, with respect, that did not start in 1974. The pattern of domestic change has been going on for at least 20 years at a very radical rate and the fact that there has been such a marginal reduction by the CEGB could not be explained by the comparisons we have had, or have I missed something somewhere?

(Dr *Chester.*) There is another factor and that is the mix of industrial use of coal and the general trend of industry over the last ten years, both because of recession and the particular mix of British industry, the heavies being less accentuated and the lights more accentuated. But if we could rephrase the question, if we put it as more sulphur per unit of coal burnt over that period, the answer is no. If we put it as more sulphur per unit of electrical energy generated, the answer is that we have put out less because our efficiency of burn has improved year by year by small amounts, so that in terms of the amount of sulphur we put out, it reflects the demand for electricity and the amount of coal we burn.

Chairman

7. Can we move on to the effects or possible effects. In paragraph 2 of your memorandum you talk of the wide spectrum of scientific views that exist as to the consequences of these emissions. I have to say that the evidence that we have received so far seems to break down into two classes. In Germany and here those scientists who seem to be supporting the energy-generating industry take the view that not much damage is being caused or the damage is caused by something else, whereas everybody else seems to take a different view entirely. Those of us who are lawyers do know it is always possible to find an expert witness who will support a particular case if one looks hard enough, but I do not want to be unfair to you. Are your scientists free to publish the results of their researches irrespective of what their conclusions may be?

(Sir *Walter Marshall.*) Yes, indeed, and, Chairman, you are quite right to make that observation that you have made. I think there is perhaps one difference in our case. I was struck by the most dramatic observation I have made since I came to the CEGB as to how little is known about this subject and how badly based is our scientific understanding compared with the subject which I have come from, namely, the nuclear business. In the nuclear business because the effluents are radioactive you can follow where they go and because we have had many decades of research on that we know very much more about the environmental impact of nuclear matters than of non-nuclear. That contrast in the state of our knowledge struck me very deeply and I do not think that it is a tenable position because the argument could simply go on forever if we do not resolve it. That is why we have taken the initiative to encourage the Royal Society with the Scandinavian Royal Academies to work on this subject, and I have great hopes that that will remove the controversy and give us a sensible scientific consensus.

Mr Freeson

8. I take it from that very interesting and, I suppose, welcome general statement, so far as it goes, that there has been too little, perhaps far too little, research undertaken by the CEGB itself in this field over the last 20 years. It was 1965, if I remember correctly, when fears began to be expressed about acid rain being caused by emissions from power stations in this country. The Scandinavians were already talking about it. Are we to understand from that last answer that in the last 19 years the matter

[Mr Freeson *Contd.*]

has been treated somewhat complacently or relaxedly by the CEGB?

(Sir *Walter Marshall.*) No, I think it is a different matter and the Chairman has hinted at that already. There is a limit to what the CEGB itself can do. It is like the tobacco industry doing research. The results are always so doubtful and questioned and I think that is why we have taken this initiative essentially to get the Royal Society to do the research in blind trust. I would also remind you that whereas ten years ago there was a great deal of concern about damage to forests in Scandinavia, the Scandinavian scientists themselves assured us in 1982 that they could detect none and, therefore, I think we have behaved quite responsibly. That is why the predominant worry at the moment in Scandinavia is the damage to fisheries and to surface water and that is where we are mainly concerned.

Chairman

9. There are three areas where indications have been given to us that damage might occur as a result of the emissions. One is to forestry, the second is to buildings and the third is to aquatic life, fish in lakes, so I wonder if we could take each of those in turn. In so far as forestry is concerned, the thrust of your memorandum is that sulphur dioxide in itself when converted into sulphuric acid apparently does not have the adverse effects it was originally thought to have. I think the idea was started by a German, Bernard Ulrich. Now the Germans seem to think perhaps photochemical processes, ozones and nitrogen oxides might be a more significant cause of the damage that is being suffered and you seem to say that in your paper. That was what we seemed to understand from our recent visit to the Black Forest, but nitrogen oxide is produced by your power stations in quite significant quantities. I would like to ask you, therefore, after that preliminary statement, first of all, am I right in my understanding of the scientific evidence that has been given and which we have tried to indicate to you, and secondly, what are your proposals concerning nitrogen oxide, if my assessment is correct?

(Dr *Chester.*) If I might respond to that, I agree with what you said but you did not say all that I think needs saying. With regard to forest damage in Scandinavia, right up until the Stockholm Conference in 1982 the situation was that earlier they had suspected there was damage which resulted in reduced growth and the evidence for this was tree ring measurements. By 1982, when they had done more work, the experts made very clear statements indeed, which are on record and explicit, saying, in effect, if there were the same thing over a longer period it should be detected in the diminution in growth of their trees, and they said the same went for Norway and Sweden. In support of Sir Walter's remarks, the Swedes are on record in 1982 at a meeting called especially for the purpose of reviewing the situation as saying they could not detect damage to their forests and that is the basis for Sir Walter's remarks. With regard to the German question, we have to ask the question, what is the German forest damage due to. There have been theories that it was due to acid rain affecting soils, but they do not seem to stand up to tests in important respects and the view is emerging that the damage bears most resemblance to ozone damage but cannot be regarded as ozone alone; it looks as though it might be in combination with something else and the something else looks most likely to be drought, but that is still another scientific theory and that has yet to be put to the test, as do others. We have not suggested to you that ozone in combination with nitrogen oxides is a likely explanation for the German forest damage; that would be a hypothesis that would need testing. What is accepted in our paper is that emissions of nitrogen oxides and hydrocarbons together with sunlight are the precursors of higher than natural ozone levels, so that if the ozone hypothesis is, in fact, proved correct, either singly or in combination, then NO_x emissions are relevant to that.

10. Let us take that. Let us accept for the moment it is ozone; and nitrogen oxide is a necessary ingredient in that recipe to produce ozone. Does not then your Board recognise that there is a responsibility there?

(Dr *Chester.*) I think we have to ask then about the long-range transport of ozone. May I make two points. The formation of ozone is one requiring a mix of pollutants, as I have said, plus sunlight. The suggestion that we might contribute by our action in the UK to ozone levels in Germany needs exploring. It is not something we have looked at in detail. The ozone hypothesis is relatively new but I think the consensus is that the range of ozone formation is relatively limited, 100 kilometres-ish rather than

[Chairman *Contd.*]

thousands of kilometres, so if the question is, what are British emission of NO_x contributing to German levels of ozone, that is a very big question mark. But we certainly contribute to British levels of ozone which are much lower than German ones.

11. That is not quite the question. Of course, it is relevant. The question is, are we contributing to ozone and, although the effects may not yet be apparent here, in this country, if we continue doing this without taking counter measures might we find ourselves in a few years time in the same position as Germany are finding themselves in at the moment? Because their history is one of signs of effects on growth in the mid-1970s, a very slow increase, and then a dramatic change in the last two years, which is what has startled them. It could be—I do not know, and this is where we seek your help—that we are five or ten years behind because of differences in climatic conditions the situation the Germans are in at the moment.

*(*Dr *Chester.)* I think there are a number of possible differences. The first one, I think, is indeed the climatic question because the nature of the forces affecting the climate in the United Kingdom is different. We have a maritime regime, Germany is closer to a continental regime. It is certainly the case that in so far as there are good measurements of levels of ozone in the United Kingdom they do not reach the high levels they do in Germany or with nothing like the frequency. In one year whose measurements I recall recently there were 104 occasions when a particular value was exceeded in Germany and only once was that same level exceeded in the United Kingdom. So I think climatically we may never be in the same position as Germany is in terms of concentrations of any pollutant. I think another question is the relative emissions: from the figures I have seen—and I do not put great stock by them because inventories of hydrocarbons and NO_x emissions are rather poor—the proportions of NO_x and hydrocarbons in relation to sulphur dioxide emitted in Germany look higher than they are in England. So I think the first point is that we cannot make the assumption that we will have the same levels as in Germany. Indeed, I think there are good reasons for expecting not. With regard then to possible damage caused by them, I think you would really want, would you not, to question the Forestry Commission but I think the question of whether our soils and our tree species are the same arises. I am told by my own people that the particular species that was first observed to have the problem in Germany, the silver fir, has been known to exhibit die-back over many, many decades, possibly centuries, which has been attributed to drought. It may be that we are looking here at a combination of ozone and drought which showed up first in silver fir; but there is no automatic reason to expect that we are simply lagging in time behind Germany.

Mr Smith

12. I would like to raise two specific points, Chairman. First, you say that in 1982 at the Stockholm Conference the Swedes said they had no evidence of damage to their forests. We are now in 1984. Are the Swedes still saying the same?

*(*Dr *Chester.)* No. The Swedes in the last few months of 1983 began to observe some of the same symptoms on some trees as were observed in Germany and the point that has been brought to me rather forcibly by my Swedish contacts is that 1983 was the driest summer and the sunniest summer in Sweden for about a century and the year in which the German problem began to be apparent was again a very hot, dry year. Now, hot dry years are years with lots of sunshine when you would expect both ozone levels to be high and water supply to be short. So I see no conflict between these two statements and, indeed, that to me seems to be quite a good pointer to the fact that ozone plus drought must be looked at as one of the prime hypotheses to be tested.

Mr Chapman: There is a conflict of evidence because we were specifically told, putting it in my layman's language, that there were wet weather years in Germany in 1981 and 1982. Clearly there is a conflict of evidence. That is an indirect contradiction to your implicit suggestion that drought is or could be the really significant factor.

Mr Roberts

13. We were told more than that—the heavier the rain, the worse the damage in certain situations in Germany.

*(*Dr *Chester.)* If I might respond to that, there is no conflict in your statement because, once you have damaged a tree, it does not necessarily follow that it is going to recover the next year and the fact that

[Mr Roberts *Contd.*]

there have been several wet years in between may be quite irrelevant. The point is what caused it in the year that caused the damage and, indeed, ozone plus drought remains a prime contender for the initial cause. I have not seen any paper describing damage being worse in wet years. We would be very pleased to have a reference to that paper and study it very carefully. That is new information to me; I have not heard it mentioned by any of my staff.

*(*Sir *Walter Marshall.)* I thought the significance of your questions was that you quoted the same year as the dry year and the wet year—1982, I thought?

Mr Chapman

14. We will have to check the papers we got in Germany. But, you see, the other point made specifically on this point is that there have been droughts in Germany before and, therefore, that leads to the assumption surely that even if drought is a factor, it is drought in conjunction with other things.

*(*Dr *Chester.)* That is not at all inconsistent with what I have said. I have not suggested, I hope, that drought is the only cause of the present damage. I am told by people who I believe know their subject that die-back of silver fir has been observed in Germany decades ago and was then attributed to drought.

Mr Roberts

15. We also saw young new trees damaged recently because the light had reached them because the older trees that had their foliage above them protecting them from the light had died and allowed the light on to the younger trees. Those younger trees could not have been damaged by the drought and something else because they were not damaged until the older trees that were damaged at the time you are describing when the drought took place had actually died and let the light through.

*(*Dr *Chester.)* If I could pick up two points which I think are still around, can I be clear on dates? The Swedes found their first signs of die-back, to my knowledge, late in 1983 and in Sweden in 1983 it was the driest year for something like a century. The Germans, I believe, first found their damage in the period after 1975–76 and that period was one of the driest on record. At Kew from May 1975 to August 1976 was the driest period of 16 months on record since 1698 and in Germany I believe it was rather similar—a very longstanding record was broken. So the two dates are 1975–76 for Germany and 1983 for Sweden.

Chairman

16. The point that was made by Mr Chapman was that in 1980–81 in Germany those were regarded as excellent wet years but the damage increased substantially in those particular years and, therefore, it was not related or is not related in their minds to drought. I think that was the point that was being made.

*(*Dr *Chester.)* I understand the point being made, Chairman. I think it begs the question of how long it takes the tree to respond and to show symptoms, and I do not know the answer to that question. It seems to me to be a relevant question.

Mr Smith

17. The other point I wanted to ask about was the mention of silver fir, because you said that the silver fir in Germany had been known to exhibit signs of decay for many years.

*(*Dr *Chester.)* Damage—not decay. Die-back.

16. The evidence we received in Germany was that, whilst the silver fir was the first tree to show signs of damage and deterioration, it is now affecting other forms of tree and, whilst at one time they had thought both the Scots pine and deciduous trees might be immune from the effects, now both these types of tree were also showing signs of damage. Given that as a recent phenomenon in Germany, do you still think that is due to drought as well as ozone or not? Secondly, given that the forest in Scotland, for example, have quite considerable quantities of Scots pine, does that not lead you to fear for the possible future symptoms which we may see in Scotland which may be happening later than the symptoms we are seeing in Germany?

*(*Dr *Chester.)* If I were to be asked for the main differences in atmospheric pollutants between Scotland and Germany, to explain why, for example, Germany has observed this phenomenon in a variety of trees now and Scotland has not, I think I would find that ozone differences are

[Mr Smith *Contd.*]

marked and the quantity of acid rain, or total annual deposition, is quite comparable. Acid deposition, as you know from a recent report, in the West of Scotland is about the highest in the British Isles taken over a year. This does not establish a cause. We need a cause for the damage, yes. The symptoms do not provide the cause. What is observed by the watering of trees with acid rain, for example, at extreme pHs? In fact, nobody has been able to produce damaged trees with watering or spraying with acid except at acidities far more acid than we experience in acid rain. So the point you are making, as I understand it, is that they do not establish a cause.

19. You have not answered my question, I am afraid—or at least my first one. The signs of damage in Scots pines and in deciduous trees in Germany have only become apparent in the last couple of years. Do you attribute those to drought as well as the ozone effect or to something else?

(Dr *Chester.*) Without knowing anything about the symptoms you are talking about on those trees, I would not want to express an opinion.

(Sir *Walter Marshall.*) I think our difficulty is that we are essentially on the cause of damage agnostic. We are saying we do not think we understand that. We are doubtful of some, or many, of the arguments that have been advanced and, in referring to alternative explanations which Dr Chester did refer us to as a hypothesis, we are not jumping to the conclusion that we necessarily understand that. That would be the reverse of what I had said earlier. I do not think our understanding of this subject is anything like good enough. I just simply think that simple arguments about acid rain do not look to me, on present evidence very plausible. I think the line of argument you may now have in your mind—that nitrogen oxides are more important—as a judgement of intuition may turn out to be correct.

Chairman

20. If we may pause there, under the generic term "acid rain" we are considering all forms of emission that produce pollutants that could affect vegetable life in the way we have observed and sulphur dioxide is only one of the pollutants that is emitted that produces sulphuric acid in the acid rain. But equally of concern to us is NO_x, nitrogen oxide, and the combination with sunlight and other hydrocarbons producing ozone which apparently has this possibility of damaging trees. You produce, if I may say so, 50 percent of the nitrogen oxide that goes into our atmosphere. This is why we keep on pressing you on this matter.

(Sir *Walter Marshall.*) Yes, Sir Hugh, and what we had better find out is which it is that is of importance because, if indeed it is the nitrogen oxides and if indeed there is a risk to our own forests as well as the Scandinavian forests, then indeed we had better do something about it.

Mr Roberts

21. You accept that one of them is important?

(Sir *Walter Marshall.*) I am not sure. I simply do not accept any of the scientific arguments I have yet seen, but we are trying to find out as rapidly as we can.

Mr Alton

22. In fact, Chairman, when we were in Germany we heard much the same sort of arguments from the scientists, your counterparts in the Germany electricity companies; even though they said there was dubious evidence, nevertheless they accepted the need to install desulphurisation equipment into many of their plants. I would like to ask you, first of all, regardless of whether the evidence is proven that acid rain (we were told that was a misnomer anyway) is the cause of the deaths of the trees in places like the Black Forest and damage to buildings or indeed to lakes and rivers, are you satisfied that it is reasonable in this country that SO_2 emissions should now be over $2\frac{1}{2}$ million tonnes a year and NO_x is being generated at the rate of 0.7 million tonnes a year?

(Sir *Walter Marshall.*) You have to have a balance and it is a balance of judgment as to what you place most importance upon. You can construct an argument to say that the mere fear that there is a chance that this can cause environmental damage should drive us to technologies to prevent the emissions of these too, and I am nervous about that. I have a statutory duty, and the Board has a statutory duty, to produce electricity at the cheapest possible price consistent with protecting the environment. I am not saying that I want to maintain our present practice indefinitely. I am simply saying that at the moment I see enough

[Mr Alton *Contd.*]
arguments that discount that and I want to be sure—and I have tried to set about in the best way I can to establish—what the scientific facts are. In the meantime we have put in hand the actual programme which I think you have in Annex 2 so that, if we discover that we must move and we must do something, we will be able to get on with it that way.

23. Your counterparts in Germany and America and Japan are proceeding to do precisely those things without waiting for conclusive scientific evidence. Are we not lagging behind in developing the environmental technologies of both Germany and Japan?

(Sir *Walter Marshall.*) In Germany they must because the Parliament has just passed a law and I am not sure they are going to manage it, but they have no choice in the matter. I was in Japan only a month ago and, indeed, they have had some very elaborate apparatus for eliminating acid rain and I cross-examined the utilities there very hard indeed. This was entirely due to the smog conditions that are created in that dreadful industrial belt along the West Coast of Japan. I asked if they had any evidence whatever of damage to their vegetation or their fisheries and they said, no, it was the irritation to human beings that was worrying them. It is something similar to the Los Angeles smog. So they are certainly taking steps, and have taken steps, to eliminate that.

Mr Alexander

24. You have been working on this problem for some time and most of us have seen the very impressive and thorough work you are doing down there. How soon would you expect you will find the answer to this problem in view of that thorough work? Will you find it by cooperating with your counterparts in Germany and elsewhere, or do you expect the Royal Society to find the answer first?

(Sir *Walter Marshall.*) I think the Royal Society will find the answer first. I think they are setting about it rather efficiently but Dr Chester is closer to it and he might make you a different guess; but I am giving you my personal judgement, because I think it will be very detached and dispassionate.

(Dr *Chester.*) If I may – simply to say I think the things go in parallel. We are not relaxing our own research effort one iota. In fact we are expanding it. Because of the Royal Society fund we would expect there to be a profitable exchange of scientific information between the two. On the forestry side as that problem has loomed larger we have swung effort into that direction and we will have a member of staff seconded to Germany starting later this year. So we are making every effort to work with people and certainly not to rely just on our own research, although we think our research contribution is probably one of the biggest anyway.

Mr Miscampbell

25. Could I ask you a question I ought to have asked you at the extremely interesting meeting we had a fortnight or three weeks ago when we went down to see you. Obviously we come up time and again against the whole question of costs. It may be an extremely naive question but can you tell me, does the removal of sulphur dioxide and nitrogen oxide have to go hand in hand? Or say nitrogen oxide proved to be the devil, can you remove that more easily than you can remove SO_2 or do you just have to take them both out by the use of expensive plant, which puts 15 per cent of whatever on the price of electricity? Say we were to find it was only nitrogen—would that help you?

(Dr *Chester.*) Up to a point you can take nitrogen oxide out by modifying the combustion conditions. As you have seen from our programme, we are going to try that technique on one of our power stations. That requires the development of a special burner first which we will put in. We will also try modifying the pattern of combustion even without a specially new burner. Both these approaches to reducing NO_x have already been tried elsewhere. They are not free of their own problems and can produce increased corrosion. We have coal in the United Kingdom with high chlorine which leads to higher corrosion than other people suffer. We will have to try it. In so far as it is successful—and in boilers where it works it might produce a 30 or 40 per cent reduction of NO_x—then your operating cost, if you do not run into corrosion problems is very small indeed, ideally zero, and your capital cost is a good deal less than putting in a sulphur dioxide removal process. The answer to your question then is, yes, there is scope and since a year or so ago we have been mounting a much

[Mr Miscampbell *Contd.*]
enhanced programme and looking at that possibility in our own stations.

26. Is that in the hopeless expectation that there will no doubt be corrosion if you try that method or does it always seem to work out that way?

*(*Dr *Chester.)* In one class of boiler, the corner fired boiler, the possibility is less strong, but in the face fired boilers there is a very real possibility. We will have to find out.

27. And that will mean a pretty high cost if corrosion occurred?

*(*Dr *Chester.)* I would not like to put a figure to it but the cost of the trial will run to a couple of millions in engineering terms. If you want to go beyond that 30 to 40 per cent and put in a NO_x removal process in the gas stream, you are now talking about costs comparable with sulphur dioxide removal costs.

28. Which comes to the same thing?

*(*Dr *Chester.)* If you are talking about taking out 80 to 90 per cent, you are talking about costs like SO_2.

29. You can do both together?

*(*Dr *Chester.)* No, the proven technology is to do them separately with separate process plant. There have been a number of proposals for doing them in one wet process but these are not the front runners technically or economically.

Mr Smith

30. You are speaking about two different processes, one of which would remove something like 30 to 40 per cent of nitrogen oxide and one which would remove 85 to 90 per cent of it. Are you doing currently any research on the technology for the NO_x removal process which would remove the 85 to 90 per cent?

*(*Dr *Chester.)* No; we are assessing what is available commercially. You recall that this is a developing field. All the emphasis has been on sulphur dioxide. The blame was put entirely on SO_2. As the NO_x position is emerging we are devoting more effort to that. Given a limited resource, one puts it on to the thing first of all that you can do first and which is most likely to be cost-effective, which is the combustion method.

31. Following that up further—you say you are assessing the technology available. Is the only technology available at the moment available from Japan or Germany?

*(*Dr *Chester.)* There is no inherent United Kingdom technology that I am aware of, but there is quite a choice of world technology. The Japanese are the world leaders in removing NO_x from flue gas.

Mr Miscampbell

32. I should like to ask a broad political question. Say we were unilaterally to deal with this matter in Western Europe—all right, the Germans help us as well—but we are left with a situation in which the Eastern bloc do nothing and more particularly Eastern Germany does nothing. What difference will it make to our Western European problem, unless everyone cooperates? Are we really going to have to take the French, the Italians and everyone with us to achieve success, or will our own steps make any material difference?

*(*Dr *Chester.)* No, I think that is a very important point. If you look at the breakdown of SO_2 emissions around Europe, if you take East and West Europe there is a total of about 30 million tonnes a year of sulphur emitted—there are 60 million tonnes of SO_2 and 30 million of sulphur. Of that 30 million, 20 million is emitted by the Eastern part of Europe and only 10 million by Western Europe. So anything that Western Europe does by way of long range transport, if it does not have the whole hearted commitment of the East will be a waste of money and put us at a disadvantage.

Mr Roberts

33. I have one or two questions. Following on from the questions that Chris Smith asked about research into technology, it became apparent when we were in Germany that the only technology for removal of the SO_2 and the NO_x is Japanese technology. Now if Parliament suddenly decides that you were going to have to do what the German electricity supply industry has to do, how quickly would you be able to do that and would you be able, quickly, to develop the technology that was needed, or would it be Japanese technology where we would have to import the equipment etc?

*(*Dr *Chester.)* First of all I ought to make a point that should have come up earlier.

[Mr Roberts *Contd.*]
In the longer run technologies for reducing both SO_2 and NO_x do not simply consist of add-ons to otherwise conventionally fuelled plant. Perhaps the most promising technology of all in the long run is perhaps the pressurised fluidised bed combined cycle, the development of which we are pursuing at Grimethorpe with the National Coal Board. You have a lower temperature of combustion and so produce less NO_x in the first place because the combustion temperature is lower. For the longer term therefore we believe we are the world leaders now in tackling on a large scale a longer term technology for SO_2 and NO_x. Coming back to the shorter term, even the Directive in its present form is calling for 40 per cent reduction of NO_x emissions by 1995. On that timescale where it is technically feasible one ought to be able to do that by retrofitting combustion modifications. I think it is also fair to say that retrofitting a Japanese style selective catalytic reduction process for NO_x reduction would be a very cumbersome process. If you are talking about retrofitting that as well as SO_2 removal, I think you will find there is not space on most of the existing stations. The German situation may be different in the proportion of old stations to new stations.

34. One of the statements made to us in Germany by their Ministry responsible for research was that there was admittedly some dispute about the causes of the defoliation of the forests. But although you may say there is no conclusive scientific proof that SO_2 and NO_x are causing the problem, the statement made to us was that there was a very high level of scientific probability that they were contributing. What would you say to that kind of proposition?

(Dr *Chester.*) I would have to differentiate between SO_2 and NO_x because I think the evidence that SO_2 is contributing to the German forest problem is really tenuous and it has not been put to the critical test on NO_x. If the ozone hypothesis is right, and it is the front runner at the moment, NO_x emissions do contribute to ozone formation. So I would have to agree with you that NO_x reduction in Germany is important possibly for reducing ozone levels.

35. You did mention that in Japan one of the problems was the effect that sulphur emissions and carbon monoxide emissions were having on human beings. Is there any research being done in this country on the effect that SO_2 and NO_x may be having on human beings in this country?

(Dr *Chester.*) Yes, not only has there been a lot of research, but I chaired an international working group assessing the international research on the topic. I would have to qualify your interpretation of what Sir Walter said. He said they were concerned about emissions because of smog conditions, and if it is like the Los Angeles smog, sulphur dioxide does not play a part in it. It is nitrogen oxide—predominantly hydrocarbons and nitrogen oxides. Commenting about health effects, there has been an enormous amount of work, in the United States in particular, on the health effects of sulphur compounds. I can provide the Committee with a detailed international critique of it if you wish and you can see that the position is not what it looked like in the late 1960s. I can refer you to an expert opinion sought of the World Health Organisation by the Geneva Convention on the health effects of sulphur and nitrogen oxides, and you can see from that that they do not rate the hazard quite so highly and believe there are more important things to spend money on.

Chairman: For the completion of our evidence it may be helpful. Questions we asked elsewhere seemed to indicate that there was little information on the effects on the health of human beings. If you have it this may be of use.

Mr Alton

36. On the effects of the smog—is it not right to say the smogs in this country and many in Europe twenty years ago were mainly SO_2 inspired? That was put to us by a scientist we met in Germany. Could you comment on this, that it is a paradox that as that smog was removed so it made it easier for the interaction between the sunlight and NO_x to take place, which has actually created the ozone problem.

(Dr *Chester.*) What you say about the London smogs is right. The main contributor to that was SO_2, but SO_2 from a myriad of low level sources which get trapped under atmospheric forces. It is true, that as they disperse as a result of a number of things, including dispersing the gases high in the atmosphere and removing soot particles, it lets sunlight through to act on automobile exhausts and so on. If you ask the question, "What is the contribution of power station stacks to urban levels of sul-

[Mr Alton *Contd.*]
phur dioxide?" it is small. We contribute maybe 20 per cent of sulpher dioxide in urban situations.

Mr Freeson: I would not say 20 per cent is small, Mr Chairman.

Chairman

37. Before we leave forestry there is just one question I would like to ask you. It is not apparent from your evidence that you have considered acidity in fog and mists which we understand can be some ten times higher than acid rain. You, Dr Chester, did mention to us that even if you increase the acidity in rain by several factors it apparently will not have adverse effects on vegetation but in mists and fogs apparently it does exist and it is one of the concerns they have in the Black Forest. Would you like to comment on that?

*(*Dr *Chester.)* What you say is absolutely correct, that cloud water is more acid than the rain coming from it by a factor of ten. It does not seem to be the case, from quite a lot of experimental work, most done in Scandinavia, that even that would create damage to trees, and certainly not the symptoms that are observed in the German forests. The question of whether ozone in combination with such mist could be the explanation is certainly a hypothesis that needs testing. To the best of my knowledge it has not yet been critically tested.

38. So we are back to NO_x again so far as you are concerned?

*(*Dr *Chester.)* No, with respect, sir, simply another one of the many hypotheses that one must expect to have at this stage of a scientific investigation.

39. Could we leave the trees and come into towns now and the damage to buildings. Although there may not be certainty as to what has caused the damage to trees that we have seen, nevertheless it was quite clear from our visit to Cologne cathedral that the acidity in the atmosphere and in the rain was having very very adverse effects upon the structure of that cathedral, and we were told—and we have no way of testing it—that some of our cathedrals—and Lincoln was mentioned to us in particular—are similarly suffering because of the acidity of rain. Would you like to comment on that matter?

*(*Mr *Clarke.)* If I may, sir, this does go back to the definition of acid rain, if you are asking about the acid rain effects on buildings. "Acid rain" rather than the smog we were discussing a few moments ago tends to be a portmanteau word which can include almost anything the person using it wants it to. In effects on buildings it is very important to distinguish whether you are talking about acidity that arrives via rainfall on the surface of the stone or whether it is acidity formed on the surface of the stone, on a wet surface—because the view today is that the latter is the major component of the acidity that causes the damage; in other words, it is an acidity that is formed on the stone by atmospheric concentrations of gases, SO_2 and NO_x in particular, dissolving in the wet film on the surface of the stone. The amount that actually arrives from the clouds as acid rain is very small in comparison, almost negligibly small, and some very important work has been done both in Europe and in America in quite recent years to demonstrate this point. If I may refer you to the report of the working group on these effects under the Geneva Convention, they have a sub-group dealing with effects on materials and their conclusion was that the major source of the acidity was local emissions in the case of corrosion of buildings.

40. You see Cologne Cathedral was said to be in the direct plume of power stations, and that the side of the building in direct line with the plumes was that which suffered most, that is at the windward side and not the leeward side of the building. They were absolutely convinced that sulphur in particular was the main culprit from their power stations—but that is by the way. The question I wanted to ask you is this: in the researches you are carrying out have you got under test different building materials—limestone, Portland stone and all the rest of it—subjected to acid concentrations to be found in rain in varying degrees?

*(*Mr *Clarke.)* Yes, we have such a programme of research which has been going on basically for decades. We had some studies done on the effect of corrosion on metals, particularly zinc specimens, but more recently we have set up throughout south-east England and in the Midlands a number of sites specifically for testing the effect of corrosion on a whole range of materials and surface coatings such as paint. This work is under way.

41. Do these experiments which have been going on for decades show that stone

[Chairman *Contd.*]

is dissolved and perished by the effect of sulphuric and other acids upon it or not?

(Mr *Clarke.*) The work that has been going on for a long time, as I mentioned, was on zinc. It is the surface coating of galvanised metal and there is a great amount of stock of this at risk in the country in galvanised corrugated iron and chain link fencing and so on. It is the predominant material used for protection against corrosion, so that is why the focus was on that. The analysis of those studies is still proceeding. It is tending to indicate that there are enhancements from the effect of sulphur dioxide in the atmosphere but it is by no means the only mechanism causing corrosion. It is a contributor to the corrosion.

42. Since the Clean Air Act we have found it possible to clean up our major buildings. This building itself is now being cleaned, the Abbey is being cleaned, Whitehall is being cleaned. There seems to be very little point in going to all that expense if they are slowly dissolving away because of the acidity in the atmosphere and you do not seem to have evidence yet or your experiments do not seem to have been directed towards that particular problem?

(Mr *Clarke.*) If I may say so, the report of the working party of UNECE is a very able and clear summary of the current knowledge on this topic. Yes, there are effects of corrosion and they are caused by sulphur and nitrogen oxides in the atmosphere but they are not the sole corrosive agents. They are not the sole cause of stone failure. Perhaps to illustrate that point, all the limestone caverns in the world, the Cheddar Gorges and the Kentucky Caves, were eaten out by acid rain long before man appeared on the planet. They are the result of dissolution in carbonic acid which came down in the rain, so the effect on stone is age-old and will always be there. What is the additional contribution from atmospheric pollution is a subject that still needs some elucidation.

Chairman: Because it could be very costly to make good eventually.

Mr Freeson

43. I do not want to go back hundreds of thousands or millions of years as to the effect of acid rain on the Cheddar Gorge and elsewhere, but I would like to get a clear answer, because I do not think we have had one, to the question you put, Chairman. How long has the CEGB been undertaking its own research into the effect of either of the substances with which we are concerned on buildings, on stone and brickwork? When did this work start, if, indeed, it has started at all?

(Mr *Clarke.*) Yes, it has.

44. When?

(Mr *Clarke.*) I cannot recall the exact date—about two years ago, the work on stone and building materials of that kind. The work on metal corrosion has been going on for a decade.

45. I understand that. I am asking simply about the stone and brickwork. Are we to understand that after all these decades of concern about the effect of pollution on all kinds of buildings going well back into the fifties and, indeed, the forties and thirties, only two years ago the CEGB took this as a serious research question?

(Dr *Chester.*) If I might respond to that, I think it is very relevant that the work we have done over the period since 1950 at least on the dispersion of SO_2 in the atmosphere is directly relevant to the answer. We pioneered a study, the physical measurement from mathematical modelling, of the dispersion of SO_2 at any height in the atmosphere, so that you know what level we are producing in any one place. The result is that it is very clear that the major contributors to urban levels of NO_x or SO_2 are a myriad of urban sources. We have concentrated on those things where we are clearly the prime producers and that is why our research has had this concentration.

46. I did not ask that question and we are entitled to get an understanding of the position. First of all, I have to say I do not accept that a 20 per cent contribution in the urban environment is small. It may be small out of many sources in total, but it is not small in itself. That is point one. Point two: I asked why it was only two years ago that research was undertaken by the CEGB into the effect on buildings. I well understand what was done in the wake of the 1956 Clean Air Act. Indeed, I understand that the CEGB were working on this even before then. I well appreciate that. I am asking a particular question not about that but about research into the effect on buildings, which started two years ago.

[Mr Freeson *Contd.*]

(Mr *Clarke.*) I think it would be wrong, Chairman, to assume everybody has been working on this. A lot of work has been done around the world which we were monitoring. The reason why we started to take a greater interest and actually set up measuring stations of our own was our conviction that the work being reported still lacked a number of important elements in the design of the study. We also at that time were involved in the work under the Geneva Convention of the working group and contributing to that group, and this work is coincidental with the formation of that particular programme, which, in fact, identified the effect on buildings first after the initial signing of the Convention as being the major item for study.

(Sir *Walter Marshall.*) I have understood the nature of the question and I found it a little difficult to understand the thrust of it. Could I answer in the following way, and let me stress that I have been Chairman of the CEGB for two years but it is a coincidence; two years' research is just a coincidence, nothing to do with my arrival. There is always a matter of judgment of what we should be doing and what we should not be doing, but suppose that we had, indeed, done research on buildings. I think that the Chief Scientist of the Department of Energy and the two Chairmen of ACORD might very well ask, "Why are you doing that if you are sure you are only contributing 20 per cent of the problem? Surely that responsibility is mainly the Department of the Environment's and you ought to be making a contribution to that pro-rata?" I think it is very hard to argue we should be taking a major responsibility in that if that is the percentage that we think we might be contributing. We have participated in a number of international and national studies and I am sure Peter Chester can give you the details of that.

Chairman: What we are concerned with is to discover what research is taking place and what the results of that research are, if any. We now know you have been doing it on buildings for two years but you are not yet in a position to say what the effects of those researches are.

Mr Alexander

47. Lincoln Cathedral is in the direct flight path, as it were, from the Trentside power station. Have you done any work or investigations on the fabric there and, if you have, have you compared it with the existing situation in similar buildings, say York Minster? Is there a difference?

(Mr *Clarke.*) The direct answer is no, we have not worked on Lincoln Cathedral. I remember some studies done a great many years ago on Peterborough Cathedral, which is perhaps a somewhat similar kind of city and location, which gave some quite interesting results. At that time there was a small power station in Peterborough quite close to the cathedral and the cathedral authorities were worried about the direct impact of the plume on the fabric of their building. As a result, we monitored the SO_2 levels at the top of the cathedral. The interesting point there at that time—and perhaps this is anecdotal—is that the measuring instrument was put inside the cathedral overnight and recorded far higher pollution than was measured outside because of the cathedral's own heating apparatus. But the point I was trying to make earlier about the definition of acid rain and the concern about the pollution is a very relevant one when it comes to considering the control of this kind of damage because if the major contribution comes from local sources, as this working group reports, then those are the areas where the controls are necessary if you are going to reduce this pollution.

48. So is it news to you that Lincoln Cathedral may well be suffering from the effects of some sort of acid rain?

(Mr *Clarke.*) No, it would not be news. I would expect virtually every building in England would be suffering some corrosion as the result of air pollution but whether it comes down in acid rain or not is the point I tried to make. I asked my chemist colleagues how long it would take rain at pH 4, which is about the lowest recorded, to wear away one inch of limestone and the answers vary between 5,000 and 20,000 years. We know that the corrosion rates are very much higher than that. The measurements at St Paul's Cathedral, Cologne Cathedral and elsewhere are very much higher, so there must be another mechanism and it is not the amount that comes down in the acid rain. It is the accumulation of the local pollution being absorbed in the wet film on the stone.

Mr Roberts

49. You say you have been doing research for two years. I assume you are

[Mr Roberts *Contd.*]

doing research in laboratory controlled situations and are also actually doing investigations into what is happening to specific buildings. Could you tell us about what you are doing, which specific buildings you have been looking at? With regard to speed, we saw the stone that was used less than 50 years ago, or about 50 years ago, to restore part of Cologne Cathedral now dropping to pieces as a result of the pollution.

*(*Mr *Clarke.)* Yes, I can quite accept that. As I say, St Paul's is an example very much nearer home, though it is interesting that a limestone in two different parts of the cathedral shows totally different reactions to the effects. You can still see the original mason's chisel marks on part of the stone of St Paul's whereas other parts have dissolved away. To come back to your question, the way we are conducting this experiment is to expose standard specimens of material in standard conditions at a station where we are also monitoring the air pollution levels, the rainfall, the humidity, and the meteorological conditions. It is not been done on individual buildings, we are not looking at a particular building and noting the effect. We are looking at specimens of stone, of metal, of paint, on various substrates exposed in standard conditions at different sites which vary from those in the open country to those in the most polluted areas. It is the comparison between these that will be the interesting factor. It is one of those kinds of experiment where you really have to run it for a couple of years, accumulate the results and analyse them, before you can reach any conclusions.

50. Can you not take pieces of stone at different stages of corrosion or destruction on various buildings throughout the United Kingdom and do some examination of those to see what is happening?

*(*Mr *Clarke.)* You can do this. It is not a very clear way because after the event you are never quite sure how the sulphur or nitrogen oxides, or whatever acted in the corrosion. I mentioned earlier very good work being done in the United States at, I believe, the Massachussets Institute of Technology. They have a very expert laboratory working on the corrosion of stonework and they have produced some very elegant and remarkable work showing the actual mechanisms by which the carious air pollution is absorbed in the individual droplets and converted to acid attacking the stone beneath that droplet. It is already very well reported in literature.

Mr Alton

51. The state of Cologne Cathedral had a fairly dramatic impact on all of us. The chief stone mason employed some 60 people permanently trying to repair the building and, indeed, he said it would soon become just a replica of a replica, some of the stones had been replaced several times in the last 20 years. Is there any comparable building in the United Kingdom suffering to that extent? It may be because we do not have any buildings suffering to that extent or quite so dramatically that the consciousness in the United Kingdom is not as great about this problem as may be it is in West Germany having regard to the costs of dealing with stone corrosion and the cost of the putting right of forests and so on. Herr Stranger, one of the Ministers of the Department of the Interior to whom we talked, told us that the cost involved about 30 per cent on domestic fuel bills and industrial fuel bills of German factories. Have you any estimates as to what it would cost to put in the kind of plant they are putting in in West Germany and what it would cost the average domestic user and the average industrial user in the United Kingdom if you were to take similar measures?

*(*Mr *Clarke.)* I would like to deal separately with the two parts of your question. I believe you asked me firstly if there was any comparable building in the United Kingdom to Cologne Cathedral. I think a number of our important buildings are the subject of considerable concern. St Paul's comes immediately to mind. Quite a lot has been written and quite a lot of investigations have been done on that particular building but other buildings throughout the country must surely be in the same category. One I do happen to know of is Lichfield Cathedral where the rate of replacement of the original stone is very high indeed but that, I think, is mainly because of the very poor quality of the stone. It is not a lasting material. This stresses the point I made earlier, that stones from different locations, different quarries, that look the same actually behave extremely differently when exposed to the same atmospheric conditions. The porous structure of the stone is an element in whether or not the corrosion occurs. Whether that is the case in Cologne I am just not expert on. As to the cost, we can give the Committee an estimate of the cost of meeting the requirements of the current directive that is being tabled by the Commission which, as I am sure you know, calls

[Mr Alton *Contd.*]

for a 60 per cent reduction in SO_2 and a 40 per cent reduction in NO_x and particulates from large combustion plant. That we estimate would increase the cost of generation at the stations affected by about 9 to 10 per cent and would raise our total cost of generation by about 5 per cent. Now, that would be passed on to the consumer at about that level, but that is only on the retro-fit side of the situation because we have at the moment no plans for new plant. We really cannot crystal-gaze into the next century to know how many new stations we are building but that percentage could rise in some cases.

Mr Freeson

52. On this particular point I will not for the moment quote it, because I do not wish to do so unless I feel I have to; but I saw from a very authoritative source recently a figure attributed to the CEGB of 15 per cent. Why the disparity?

(Mr *Clarke.*) Can I try to explain that there are a number of figures being given to a number of different questions. The increase in the capital cost of the plant in order to fit this kind of equipment by flue gas de-sulphurisation would be of the order of 15 per cent. The increase in capital cost of the plant would be 15 per cent, the increase in the running cost of the plant could be anywhere between 9 and 15 per cent.

53. I was told the effective result would be 15 per cent increase to the consumer. Now, where does that fear come from because it was from a very authoritative source. I will quote it if necessary.

(Mr *Clarke.*) I cannot answer where that came from.

Mr *Freeson*: It is a matter of two months back.

Chairman

54. All we can do is to take the evidence given to us now. What we are being told is that the capital cost will be 15 per cent and the running costs will be 5 per cent per annum. It is the 5 per cent——

(Mr *Clarke.*) No, running costs at the stations where the plant is fitted would be about 9 or 10 per cent higher. The effect on the whole of the CEGB would be to increase our cost of generation by about 5 or 6 per cent.

55. Between 5 and 6 per cent would be the cost that the consumer would have to pay were it to become the policy of Government to insist that you took steps to eliminate the emission of sulphur dioxide and nitrous oxide?

(Sir *Walter Marshall.*) Sulphur dioxide.

(Dr *Chester.*) You said, Chairman, "eliminate". The sum quoted was the cost of meeting the directive which is to make a 60 per cent reduction.

56. I stand corrected—to fall in line with the proposals coming out of the European Commission on SO_2 alone.

Mr Smith

57. If we went for an 85 per cent reduction in NO_x in power stations what would the cost effect be then?

(Dr *Chester.*) Rather similar if it were 85 per cent and we had to put in one of these gas treatment processes and were there space available to put it in—you will recall we had very much less hard information on nitrogen oxides. Roughly speaking, the same.

Chairman

58. But did you not suggest to us earlier this afternoon, Doctor, that dealing with nitrogen oxides was cheaper because you could deal with the burners?

(Dr *Chester.*) At the 30 or 40 per cent level, yes—but at 85 per cent——

59. Changing the boilers would not be sufficient?

(Dr *Chester.*) No, you would need quite a new technology for that.

Mr Miscampbell

60. You make the distinction in the actual cost to the consumer because a large proportion of the electricity is being generated by stations which do not produce this.

(Mr *Clarke.*) That is the reason why the 9 or 10 per cent of the stations affected produce the 6 per cent overall.

Mr Roberts

61. I thought the majority of your production did come from fossil fuel power stations?

[Mr Roberts *Contd.*]

(Mr *Clarke.*) It does.

(Dr *Chester.*) Would it be worth recapitulating the figures, one at a time?

Chairman

62. That would be helpful because we must produce a report and we must make sure we have understood the evidence correctly before we give any advice of our own.

(Dr *Chester.*) If we go through it—the cost of retrofitting an FGD plant and FGD equipment to an existing station as Mr Clarke has indicated will be of the order of 15 per cent of the capital cost. If you now amortise that and add the running costs, the cost of the electricity produced from that station would increase by 9 to 10 per cent, as he said. Clearly the effect on the CEGB's production costs—and that is a distinction we must make and may not always have been made carefully—must then depend on the number of stations you fit. If you take as an example the amount we would have to fit to comply with the Directive in its present form, that would mean fitting to something like 20,000 megawatts of plant. The effect on our production costs, taking last year's coal burn situation, would be approximately 5 or 6 per cent of our production costs. Now the effect of that on the consumer depends on what kind of consumer you are. If you are someone taking it on a very large scale industrially the effect on you will be rather similar to that; if you are a small consumer at the end of the distribution system the effect will be less than that in percentage terms. But the overall capital cost of putting in that programme on existing plant only to meet the Directive would be something between £1,400 million and £1,500 million—£1,440 million or thereabouts, that is our best estimate of using the best currently available FGD processes that we know. And I should add every time we update we take advantage of any improvement claimed or demonstrated in the process, and our latest estimates give all the credit to the FGD process in terms of improved efficiency and lower capital cost that we can.

Mr Miscampbell

63. If these requirements were imposed would it make a material difference to you in your choice between, say, producing electricity by nuclear power and producing it by coal? Would it tip the balance?

(Sir *Walter Marshall.*) It would certainly be a factor that edged it to be more favourable to nuclear. I do not think it would be at the level we are talking about. I would not call that decisive.

Mr Chapman

64. In paragraph 9 of your memorandum you talk of the Alkali Inspectorate. Are they not insisting on stricter controls on any new plant, and if so, or if Parliament decree that a new plant should have these controls, would that affect your policy of how much electricity you get from coal powered stations rather than hydro-electric or nuclear power?

(Sir *Walter Marshall.*) In the calculations we had to try to analyse the system. It is just a factor which would be fed into it, and it clearly would tend to a small degree to favour nuclear relative to coal. But again I do not think it would be decisive.

65. One final point, which is a crucial point to me. You have quantified pretty exactly and have given the figures of how much it would cost to comply with it if it were a requirement of the EEC draft Directive. Can you exactly quantify how much the sulphuric acid content and the nitrogen oxides would be reduced if you had to comply with that Directive?

(Dr *Chester.*) No, sir, we cannot. In fact we think this is one of the major scientific uncertainties. To quantify the relationship between sulphur dioxide gas emissions and the formation of sulphuric acid in rain at long distances is one of the major unresolved questions in this issue. And as you have seen in our evidence it looks very much as though photochemical oxidants are necessary for that conversion, and if their supply for whatever reason is the limiting factor then altering the emissions up or down by some margin will not make any difference to the acid formation. How big that margin is is one of the objects of research around the world.

66. Are you saying that with all the expertise at your command? We were very impressed when we went down to Leatherhead. I know scientists like to be exact but can't you even form what I call an intelligent judgement about how much you might reduce these pollutants? I understand your argument absolutely.

(Sir *Walter Marshall.*) You asked two different questions and my colleague was

[Mr Chapman *Contd.*]
trying to answer precisely. We would certainly be able to tell you how much we would reduce our emissions of sulphur dioxide, but we cannot give you any idea of how much that would, if at all, affect the acid deposition in Scandinavia.

Mr Freeson

67. But you were only asked about emissions.

(Sir *Walter Marshall.*) He asked about acid production. My colleague answered on acidity and that is different from the emissions.

Mr Smith

68. Can I ask first of all just on that, to clarify my mind—the very precise figures that you have given on the FGD processes, that would reduce your emission of sulphur dioxide by roughly 60 per cent would it?

(Sir *Walter Marshall.*) Yes, correct.

69. You have given very precise figures on that. The answer that you gave to me earlier on an NO_x reduction in emissions was rather less precise. You said roughly the same cost. Firstly, why is your information so much less precise? Secondly, by "roughly the same sort of cost", do you mean the same sort of magnitude of cost and would that therefore mean, say, a further addition of 5 per cent in electricity prices? Thirdly, is your answer on that affected by the fact that earlier on you said you had done no research on the technology required to reduce NO_x emissions by that level?

(Dr *Chester.*) If I may take the last one first—no, that is not the reason. The reason is that sulphur dioxide technology has been developed around the world a lot earlier than NO_x control technology. The point is now going back to the first question, that in 1980 one was able to go out and get either a commercial quote or an engineering design study on which you could base accurate costings, and we certainly went out and got an engineering design study made of the Wellman Lord process and we are presently having one done on the Gypsum process. On sulphur dioxide you can go to architect engineers and get a detailed costing based on experience. There are many tens of thousands of megawatts around the world. The NO_x situation is not quite like that. The one that has been used quite a lot, mainly with oil-fired stations, not with coal-fired, is the Japanese-style selective catalytic reduction process, so the pricing basis is not so good and I do not want to give you figures that are our interpretation of what the cost might be in England, but the figures we have seen lead us to believe it would come out in the same ball-park, give or take, 20 per cent, in the same range as FGD. In terms of running costs, the biggest cost of running that process is the cost of the catalyst and we again have projections from the Japanese and they come out similar to FGD plus or minus 20 per cent. It could be more. It depends on the life of the catalyst. Nobody knows whether that catalyst will last two years or only the one year that the manufacturers will guarantee. So it is the fact that the running costs that I mentioned control the cost uncertainty. It is an emerging technology without the experience, so that is why the figures are not so good. The second thing is we do not know the extent to which it would be possible to fit that process in our plant. The space requirements are large. In theory all our modern plant was built with enough space to fit in what was notionally seen as FGD plant space, but in the event it may turn out not to be big enough for SO_2 and NO_x, so there is certainly much of our plant that would not even take a retrofit NO_x removal process.

70. If you were building a power station now to produce a given quantity of electricity and you had a choice between building a nuclear power station and building a coal-fired power station and were required to put into it the technology to reduce SO_2 emission by 60 per cent and the technology to reduce NO_x emission by 85 per cent, and you were considering the capital and running costs over the next 30 years, which would be the more expensive?

(Sir *Walter Marshall.*) We have made it clear that in our judgment nuclear plant is the more economical, as it stands now, and if you add these penalties to a coal-fired plant then it is even more economical and, therefore, I think the answer to that question is simple. But, as you know, we have an inquiry about the PWR at Sizewell and cannot plan that that is what we are going to build. We are, therefore, at a position where we are, if you like, waiting for a policy decision on where we can go. I think a question somewhat similar to that which I believe your colleague was getting at is, looking to the future, what is it we would want to do. One of the important issues we

[Mr Smith *Contd.*]

would have to resolve is that if we decide, either because of Government regulations or the Alkali Inspector or our own judgment, that we must take sulphur out of new plants, it would make a big difference to us whether we would have to put in the FGD plant or whether we could bring the pressurised fluidised bed process along early enough to make that useful, and it is a question of timescale. Of course, it would matter when we needed to make that step.

Mr Freeson

71. This does interlink in a fresh way with one of the questions I was putting. Reference has been made more than once to fluidised bed combustion and the way it was put to us just now one must take it that neither the Board nor the NCB are yet in quite the position they would like to be in, to say, "Yes, we can introduce it". It is still being researched but that has been going on for a long time and we might guess, as amateurs, it must be fairly near the edge of successful economic application, or if sufficient effort were put into it on both sides it might be—a bit more in the way of resources perhaps. If there were a decision to go ahead with the kind of controls we have been discussing and it was decided to introduce that within the programme, which is virtually a ten-year programme taking the Brussels proposals as the starting-point, one would foresee then the introduction of fluidised bed combustion as a possible system in new installations within a ten-year period. If not, why not?

(Sir *Walter Marshall.*) I think it is possible we could build a new coal plant within that timescale. It is possible towards the end of that time but at the moment, as you know, the demand for electricity has fallen off and we have a healthy capacity, so that you cannot separate that out from the look into the timescale. If you, Parliament, pass legislation which obliges us to move now we will have to do that by retrofits.

72. I understand that. I was simply suggesting that if during the course of that ten years you had the kind of choice that has been put, about building alternative additional plant, then the question of introducing the fluidised bed combustion within that ten-year programme becomes a real prospect, does it not?

(Dr *Chester.*) I have to say "within it" might be misleading. I think at the end of it or within five years following it would be my crystal-ball reading. We are still at quite an early stage even though we have an 80 MW facility at Grimethorpe, and there are quite a lot of problems to be worked through.

73. Point taken. Could I go back to the question of costs which we were dealing with earlier in connection with the ten-year programme. I was not too clear from the answers during that series of exchanges whether the 5 to 6 per cent increase on consumer costs if the Commission's draft directive were put into effect would be the result of a cumulative programme over ten years or would come onto the consumer in years one, two or three. The figures have not been clear, whether it is the 15 per cent I threw into the argument a little earlier or the 5 to 6 per cent we have heard this afternoon. At what point does that 5 to 6 per cent start to operate—ten years from now?

(Dr *Chester.*) It is when that programme is fully implemented. The directive at the moment is calling for a 60 per cent reduction by 1995. To do that requires a quite substantial retrofit programme which would take all that time and the figure of 5 or so per cent on the CEGB production costs applies when that stage is reached, which would be 1995.

74. So if there were such a decision taken a £1,500–1,600m. investment in real terms would be spread over a ten-year period. It would take a number of years to complete and the result would be at the end of it, on the basis on which I have seen the figures, a 5 to 6 per cent effect on consumer costs in relation to 1995?

(Sir *Walter Marshall.*) Correct.

Mr Alton

75. Can I pursue that because there is still some haziness in my mind about this. When I originally put the question to you I was asking if you were to do the same things as the Bundesrat or the Länder assemblies decided were to be done in Germany what would ultimately be the effect on the domestic consumer, and you answered the questions quite reasonably giving the details of what would happen if you were put in line with what the directive says. What is the difference between what the directive says and what the Germany option would be if that were implemented in this country. Given that in Germany between 10 and 15 bn DM have been made

[Mr Alton *Contd.*]

available by central government towards the cost of this programme, what is the figure you would be looking for if the British programme were to do precisely what you have all advocated? What would you think would be a reasonable contribution towards the cost?

(Sir *Walter Marshall.*) I think a reasonable contribution would be all of it, but if you asked what would be my reasonable expectation then I suspect that it might well be zero. But there has been some subtlety in the wording which is worrying myself and my colleagues. We are trying, in quoting the figure to you of 5 to 6 per cent, to indicate to you our overall change in our costs. You are anxious to understand what the effect on the final consumer might be. There are, of course, some costs of the area boards, who are the distributors of the electricity, but they are modest. A more important factor is the attitude the Government might take on our rate of return while we were doing that, of course, and which comes back to the very similar question of what is the cost that the Government might absorb.

76. I still want to press you further about the comparison with Germany because they told us there that the cost per kilowatt hour was 8 to 9 pfennigs and the cost would rise by 3 pfennigs per kilowatt hour which they said could be obviously as high as a 30 per cent increase. There seems to be an enormous disparity between the 5 per cent to the consumer here which you say it would cost and the 30 per cent they told us about there. That is what I still really cannot understand.

(Dr *Chester.*) Could I perhaps help. We realise the difficulty there is in making these comparisons because what is involved is a capital investment programme, and then you have the question of what rate you should charge your capital at and whether you write it off over the remaining life of the plant. Unless one has got all those factors on the table and one knows what the production costs are, it is very, very difficult indeed to reconcile. It could very well be that they are talking about a shorter period with possibly higher interest rates, so I do not think there is a simple reconciliation we can give you. Could I offer you a rule of thumb, which is quite useful: it is a number which has emerged from a study by Environmental Resources Limited for the European Community. They have estimated various different scenarios of introduction of sulphur control in Europe. If you take one that lies around the directive or a bit below, you can calculate the number of million tonnes of sulphur abated each year and the number of millions of dollars—they express it in dollars, I will express it in pounds—which is something like £500 per tonne of sulphur abated rolling in the capital costs and running costs. That is on some kind of mish-mash of capital conventions, interest rates and so on. Our sums for the programme which we have just mentioned to you also come out at a very similar figure, £500 to £550 per tonne of sulphur abated. With that number you can almost pose the question yourself and answer it: how many million tonnes do we estimate at the moment of sulphur the CEGB emits? About 1.3 millions and the nation about 2. You can multiply that up and that would give you roughly speaking your annual cost. We have found that quite a useful guide. It looks as though it is a figure not subject to intense controversy and you might find it helpful. Can I repeat please, Chairman, that when I talk about 5 per cent or so I am talking about CEGB production costs as reflected in the bulk supply tariff, not the tariff for the domestic consumer who has standing charges and various other things.

(Sir *Walter Marshall.*) I cannot comment on the 30 per cent figure. It may be that getting sulphur out of lignite is more expensive and the Germans use lignite. It may be that they are looking for a faster return on their money. We would have to look at that a bit carefully to reconcile the numbers.

(Mr *Clarke.*) Can I offer two more possibilities? One is that the German electricity production system actually contains a lot of small power stations when you compare it with the CEGB. We have a relatively small number of quite large power stations, they have a large number of quite small stations. The costs of this kind of equipment tend to escalate a bit as you go down in scale; for the smaller stations it is more costly. That is one point. The other point may reflect the legislation itself which, in fact, calls for something to be done on virtually every power station. We are, of course, able in meeting the directive to select the most optimum group of stations to consider in order to meet it. They have to do something on every power station so this may be reflected in those high costs.

Mr Chapman

77. One final piece of the jig-saw relating to my last questions: you have told us how

[Mr Chapman *Contd.*]

much it would cost to comply with the draft directive if you had to comply with it. Obviously we know how much you can reduce your emissions both in SO_2 and NO_x. You confirm that you cannot say what the effect of those reduced emissions would be on taking the pollution out of the atmosphere, but can you just remind us that, if you did reduce your SO_2 by 60 per cent and your NO_x by 40 per cent, which I think would comply with the Eurodirective, what the result would be in terms of national reduction in emission of sulphur and nitrous oxide? In other words, you provide so much of the total in this country: what would be the overall reduction if you had to reduce by 60 per cent and 40 per cent respectively?

(Dr *Chester.*) Could I make sure we have understood your question and answer it perhaps in two tranches. You introduced your question by saying we had made a statement about uncertainty about the effect of reducing pollution. The work "pollution" can be used very widely. Clearly, if we emit half the SO_2 as we presently do, our contribution to gaseous SO_2 in the United Kingdom will halve. The point we were making earlier is, what would our contribution to the acidity of rain do, and that is an open question. If we come back then to what cutting our emissions would do on sulphur dioxide levels around the country, if we reduced by 60 per cent we would therefore reduce by 60 per cent our contribution. Typically in London, for example, that would be a cut of 60 per cent in our contribution of 20 per cent or 25 per cent, so the reduction would be something like 10 per cent in London's SO_2 levels. By putting that directive into force on our power stations on NO_x it is a little more difficult to answer. Perhaps John Clarke would make that comparison.

(Mr *Clarke.*) I am not sure whether you were really questioning our proportion of the total United Kingdom emission in your question. Our proportion of the SO_2 is about two-thirds now of the total emission, so halving our emission would knock one-third off the national total. In the case of NO_x for the figures such as they are we are probably a little less than half, round about 45 per cent, of the total UK emission. So reducing our emission by 40 per cent would reduce the national emission by something less than 20 per cent.

Mr Smith

78. And similarly twice as much if we reduced by 85 per cent?

(Mr *Clarke.*) That is correct.

(Dr *Chester.*) Could I comment on the effect of acid deposition. If you look at sensitive areas like the Galloway area of Scotland on granite, the OECD study showed most of the acid deposition arriving in that area was coming in on westerly trajectories that had been coming from the west for at least three or four days. So the effect of even a total reduction of European emission on that acid deposition must be a big question-mark.

Chairman

79. I think we have touched on most of the areas concerned except that we have not talked about fish life. Perhaps we could just finish off on that particular problem. You say in paragraph 5 of your memorandum that there is little evidence of the effects of acidification on fish life, but in paragraph 19 you say that the Loch Fleet project is to counter the effect of acidification. As those two statements seem to be somewhat contradictory, can you tell us what the Board does believe?

(Sir *Walter Marshall.*) With respect, Chairman, I believe you have mislaid the sense of paragraph 5, and I apologise if it was not clear. As I said earlier on in this cross-examination, we were agnostic about the effects of acid rain on forests, but I was anxious to acknowledge that our responsibility for fisheries and lakes looks likely to be more real. In paragraph 4, as we say, we do not think we are responsible for forests, but in paragraph 5 we are trying to say, with respect, we might be for fisheries. Therefore it is quite consistent with paragraph 19 where we are saying to you that it is this matter that is the matter that mostly is concerning us at this point in time.

80. And that is a sulphur dioxide problem in the main, is it not?

(Sir *Walter Marshall.*) Well, it could be both. We are looking at the effects of the acid rain falling on the ground or indirectly into the lakes and affecting the fish life in the lakes and rivers—both sulphur and nitrogen.

81. It comes to this, you are in doubt over forests, you are not sure about buildings but you are pretty certain about fish and lakes, so you have to do something about it, is that right?

[Chairman *Contd.*]

(Sir *Walter Marshall.*) Pretty certain. I say that that looks like the more serious of the three.

(Dr *Chester.*) Responding to your invitation to give the basis for that, Chairman, it will take a moment or two but I think it is worth doing because the position on fisheries is the furthest advanced scientifically, and in that respect Sir Walter was drawing your attention to it. That does not mean to say that as a result of it being further advanced the explanation clearly points to sulphur dioxide. I think it is worth bringing out one or two salient points. There is no doubt there are acidified lakes in Scandinavia and Scotland and North America. The interesting feature that has emerged over the last few years is that the process of acidification in the Scottish lakes has been going on individually for a long time. They were acid a century and a half ago, the ones which were examined by diatom records, and they have been getting more acid since. There were in fact fish kills and fishery problems in Norway back in the 1920s and at the turn of the century. There has not been a sudden upsurge. The process has been going on for rather longer than people thought.

82. So has the Industrial Revolution!

(Dr *Chester.*) That could very well be the case, and I would like to comment on that in a moment. The second point is that earlier mental pictures of the process were of a process akin to chemical titration which goes on within a beaker where you pour an acid into alkali, or *vice-versa*; but the lake is not in that situation. It is in surrounding soil, and 80 to 90 per cent of the water has gone through the soil first. Again, over the last ten years, the role of the soil in a particular catchment in determining the water quality has come to be understood rather better. The third point is that earlier people thought simply that the water being acid was a sufficient explanation for fish disappearing. And it is true that if you make water acid enough fish will disappear—finally they will dissolve—but the other factors in the water composition are now becoming clearer, and it is clear that fish can live in waters that are much more acid than has been hitherto thought, if there is enough calcium. So to understand the fish studies you have to bring in calcium. I will draw your attention to this relationship, which is cardinal to understanding acid lakes. *This* (*indicating diagram*) is the results of the Norwegian's own experiments in Norway, where every dot represents a lake with no fish and every cross represents a lake with good fish. It is plotted on a diagram in which we have acidity *this** way and calcium level *that*† way (*indicating on diagram*). If you are close enough you can see there are plenty of lakes that have fish in them that are more acid than lakes that do not have fish in them; and the distinguishing feature seems to be more the region of the diagram that you are in. And if the ratio of calcium to acidity is high you should have a high chance of having fish, and if it is low you are likely not to. *These* lakes *here* (*indicating*) are very low in calcium indeed. An important question to ask is, how did they get to that position on the diagram? I do not propose to answer that question for you because it is the subject of a research programme and one of the problems we put to the Royal Society. But a relevant question for you to consider is, what would happen if you reduce the sulphur deposition in these lakes? The first thing is that for lakes at the same altitude there is no significant difference in the sulphur content of the water between fishless lakes and the lakes with fish at the same altitude. The second thing is that the calcium in the water now is very likely mobilised by that very sulphuric acid coming in. The likelihood is that if you reduce the acid input then these lakes would move down *this* sector of the diagram (*indicating*) and remain in the unfavourable sector. Whatever the reasons for the fishless lakes being over *here*, whether partly due to changes in the soil for natural reasons or partly due to acid rain, the most important question is, what would happen if you reduced deposition, and it does not seem to us that it would improve the quality of those lakes.

83. You are leading us to the thought that rather than going to a lot of expense and reducing the sulphur dioxide of your emissions in order to meet this problem, we should consider instead the cost of someone adding calcium or like to the lakes?

(Dr *Chester.*) No, but in order to restore those lakes, calcium will have to be put back into them. That could provide a solution in the meantime, which the Swedes have used, while we find out why they are in that condition. We know that aluminium is implicated as well. I am making the simple point that one can contain that problem and correct

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* Indicating vertically.

† Indicating horizontally.

[Chairman *Contd.*]
it to allow time for proper understanding on which a proper long term solution can be based.

Mr Alton

84. From the evidence you have gathered so far in this country about the liming of lakes—how advantageous is that?

*(*Dr *Chester.)* There is very little information on liming in this country so far as I am aware, and the Loch Dee study will do this in part, but there is a great deal of evidence in Sweden. There is a major liming programme of lakes in Sweden which is containing the problem and maintaining fisheries—and there are glossy brochures produced by the Swedish Fisheries Board telling people how to do it. It is not full proof. One can actually precipitate aluminium and there are certain precautions to be taken, but I am told by the Swedish Fisheries Board that if they spent 200 million Kroner a year—that is roughly £18 million—they would be able to lime every lake of concern in Sweden.

Mr Miscampbell

85. Why is it that in this country before the war we used to have a 200 million tonne burn of coal and now that we have a burn of coal of one million tonnes the problem seems to be getting worse? You will say that the problem has always been there, but clearly it is becoming much more visible. Why, when we were an industrial society based entirely on coal and in the pre-war days burning it away like mad with inefficient burners did this problem not appear to be there in the same way?

*(*Dr *Chester.)* One can ask the question "What else has been changing over that period of time?" It is abundantly clear that our emissions of hydrocarbons have increased markedly in the post-war period, and presumably our emissions of NO_x similarly. So the fact it paralleled the Industrial Revolution does not necessarily mean it is one particular product of the Industrial Revolution—and over the period of the Industrial Revolution there were accompanying agronomic changes, for the reason that it was an industrial revolution, which changed people's farming and land-use habits. If you look at all the things which were going on, you do not have to focus on sulphur. The fact that there is not a difference between the sulphate contents of those lakes with fish that are good and those that are not, that alone is a reason for questioning that point.

Mr Smith

86. I have two general questions which are stepping back a bit from the detail. You have gone to great pains to try and convince us that the state of the science is in no way exact and that there is a great deal of doubt as to exactly what causes the effects which are undoubtedly visible in German forests and Scandinavian lakes and so on. How long will it be before you are satisfied in your minds that sufficient scientific evidence is available to take definite decisions about what should happen to your power stations?

*(*Dr *Chester.)* I do not think that is a question one can actually answer. Investigating the German forests has still left these questions unanswered. In ten years' time there may be still as much uncertainty there. You would still have the same question in your mind, will reducing sulphur emissions cure the problem or not. The scientific process takes the time that it takes. If you want to use its answers you go with that. If you do not have the time for whatever reason you make a decision that is not based on the science, but I cannot predict how long it would take for the explanation of the German forest damage to be found. People are working extremely hard on it and each year there is a change or complication, bearing in mind that is not unusual in science.

*(*Sir *Walter Marshall.)* Could I also add to that that I have thought it important to ask the same question that you have posed and, therefore, when we initiated the project with the Royal Society I asked Professor Mason the question you have asked: how long is it going to take. Indeed, it was very important to ask that because we had to establish whether this was a project which was expected to run for two years or five years or ten years, and he made an informed judgment. He said, "Let us make it for five years. We ought to get the answer by then. I will be disappointed if we do not get a pretty good idea beforehand." I am just giving you his guess also.

Chairman

87. What does concern us—and I should be asking you questions rather than making statements—is if it were to take five years

[Chairman *Contd.*]

to find the answers and then another five years to apply your research in technology ten years away, by that time what devastation might have been caused? I do not think any of us would want to carry the responsibility for what could be the effect of a delay of that kind, if the indications we have been receiving so far have some substance in them. Therefore, I would like to express the hope—and we are gratified to hear what research you are carrying out—that examination of the technology is going on in parallel with the inquiry into possible causes so that once the source of the problem has been identified the technology is available immediately to put into operation. I should be asking you questions but perhaps you could treat that as a rhetorical question.

(Sir *Walter Marshall.*) I understand exactly what you mean, Sir Hugh, and it is a balanced judgment between the dilemmas you have posed and the alternative is that we might spend a lot of money and then find that the effect is negligible.

Mr Smith

88. Could I follow that up. The German legislature has obviously taken a decision that despite the fact that the science is not exact the probability has led them to decide that they must grasp the nettle and embark on these costly processes to reduce NO_x and SO_2 emissions. Clearly one of the decisions we as a Committee are going to have to face is precisely that same question, that even though there is probability rather than exactitude should any steps be taken immediately. What would your response be if faced with that decision?

(Sir *Walter Marshall.*) I would much prefer it if politicians did not attempt to make balanced scientific judgments. You said that the German parliament had decided that there was a high probability that sulphur dioxide or acid rain was causing their problems in their forests. I am not at all sure that politicians are the best judges of that and I am not sure they are altogether so logical as that. I do not quite understand the political scene in Germany and, therefore, I am unable to give you chapter and verse for why the German situation went that way. I am trying to assure you that we are approaching this problem as conscientiously as we can and we are trying to balance our statutory duty to produce electricity cheaply with our concern for the environment and we have attempted to set up simultaneously and in parallel a method of resolving the scientific uncertainties which I believe will be beyond dispute. After all, we have now involved our own Royal Society and the Swedish Royal Academy of Sciences, which must be the most prestigious scientific academies in the entire world. We will, I think, get a consensus scientific opinion from that. We are proceeding with a parallel investigation of the technologies. We are not procrastinating because of the lack of knowledge of the scientific subject. If we had wanted to procrastinate we would not have asked the Royal Society to mount that exercise. We are just trying to do our conscientious job as we see it.

Chairman: Thank you for that affirmation of your objectives and endeavours. May I thank you for coming here and you, Dr Chester and Mr Clarke, for the help you have given us this afternoon.

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WEDNESDAY 23 MAY 1984

Members present:
Sir Hugh Rossi, in the Chair

Mr Richard Alexander	Mr Allan Roberts
Mr Sydney Chapman	Mr Chris Smith
Mr Robert B. Jones	Mr John M. Taylor
Mr Norman Miscampbell	

FRIENDS OF THE EARTH EVIDENCE TO THE HOUSE OF COMMONS ENVIRONMENT COMMITTEE ON ACID RAIN

By Chris Rose and Dr Claire Holman

SUMMARY

1. There is a rapidly growing body of scientific literature detailing the damage caused by SO_2 and NO_x and their acidic reaction products to the natural and built environment.

2. There is also a growing consensus that there is a linear relationship between long term average SO_2 and NO_x emissions and a reduction in acidity over large areas.

3. Britain produces more SO_2 than any other Western European country, and a major proportion comes from the CEGB's system.

4. The CEGB's 1980 sulphur emissions could be reduced by about 60 per cent by the year 1995, in line with the Draft EEC Directive on emissions from large plant, at a cost of less than 4 per cent to the electricity consumer. This is based on conservative assumptions and the real price could be lower.

EFFECTS

5. Strictly speaking, the term "acid rain" refers to the wet deposition of acidic pollutants. However, the phenomenon cannot be considered in isolation from the effects on the environment of other forms of acidic deposition and the dry deposition of the gaseous precursors: sulphur dioxide and oxides of nitrogen. Indeed, this was the conclusion reached by the Royal Commission on Evironmental Pollution during their investigation of acid rain (10th Report, Tackling Pollution—Experience and Prospects, HMSO, 1984).

6. Acid rain and its gaseous precursors cause a wide range of effects on the natural and built environment. Damage has occurred over large areas of Europe and North America. Due to the widespread damage that has been reported, it is necessary to restrict this brief discussion of the effects to a few European examples.

7. Scandinavian scientists have reported the acidification of Swedish and Norwegian waters for several decades. Research projects have included the large Norwegian SNSF programme which ran from 1972 to 1979. More recently freshwater acidification has been reported in USA, Canada and many parts of Europe including Belgium, Denmark, Netherlands, West Germany, and Britain.

8. In Sweden it is estimated that 18,000 lakes are acidified (9,000 seriously and 4,000 have lost their fish populations). In Southern Norway an area of 28,000 km^2 has been

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examined and 1,750 out of 5,000 lakes there are thought to have lost fish populations. If the present rate continues 80 per cent of the brown trout populations will be lost in this region by 1990 (Acid Rain: A Review of the Phenomenon in the EEC and Europe, ERL, Graham and Trotman, 1983).

9. Within the last five years British studies have revealed acidification in Scotland—where 22 Galloway lakes are affected—as well as episodic acidification on the rivers Esk and Duddon in the Lake District. Here many upland tarns are also affected, as well as the upper Tywi catchment and several lakes in mid and central Wales. Attempts to re-stock the Tywi have proved unsuccessful. The Welsh Water Authority has shown that native brown trout cannot survive the combined effects of acidity and elevated concentrations of aluminium found in water draining from the conifer forests in that area. In south-west Scotland there is evidence of entire fish populations becoming extinct in two lochs (Loch Enoch and Loch Fleet).

10. Fish populations are known to be affected by elevated levels of aluminium which is mobilized by acidic water. Aluminium toxicity may be especially significant in snow-melts, when a sudden surge of acid water occurs. This has been implicated in fish kills in Norway in 1976, in Canada in 1980 and in Britain in 1982–83.

11. In recent years there has been considerable controversy over the contribution of afforestation to freshwater acidification. One comparison of forested and non-afforested catchments in Norway found no link between acidified lakes and land-use. In Galloway acidified lakes have been found in both types of catchment. It appears that acid rain is the major agent leading to acidification of freshwaters but establishing conifer plantations can exacerbate the problem. This was the conclusion of the International Electric Research Exchange's investigation into the ecological effects of acid rain. The Exchange's report, to which the CEGB contributed, noted that "there are many sources of acidity within the ecosystem but together they are unlikely overall to match that reaching streams from acid rain".

12. In the Federal Republic of West Germany air pollution is damaging 34 per cent of forests, an area of 2.5 million Ha, including almost half the Black Forest. 560,000 Ha have been designated a "total damage area" where a complete loss of productivity is expected. 47,000 jobs are under threat in German forestry and the wood processing industry. The economic cost to Germany is estimated at £857m a year. 70 per cent of Germany's silver firs are now damaged and the species may be threatened with extinction in the country. Spruce, pine and beech have also suffered extensive damage.

13. Areas of damage have also been reported in Eastern Europe, the Netherlands, France, and more recently, Sweden and Switzerland. While the exact mechanisms of damage remain uncertain, there is no doubt that a rapidly worsening problem exists in Europe's forests and that air pollution is an important factor.

14. Britain's wildlife is threatened by acid rain. Species most at risk are initially those associated with freshwaters, but as studies progress others, too, may prove to be affected. Recent reports indicate a potentially widespread effect on Britain's few native amphibians. The natterjack toad is one of the few species singled out for protection under the 1975 Wild Creatures and Plants Act and the 1981 Wildlife and Countryside Act. The natterjack is known to be severely declined and thought to be extinct at several localities which were once major breeding ponds in Surrey and Hampshire. These are now too acid for the natterjack to breed. Except for the palmate newt, Britain's other amphibian's (toad; frog; smooth, common and great crested newts) may be equally sensitive. Few studies have yet been completed.

15. The osprey is a large and rare fish eating hawk with its main European population in Sweden. It is now absent from many former nesting haunts in that country. Ornithologists believe this is a result of fish losses due to acidification. A small population of ospreys exists in Scotland, but while they are observed to "prospect" the acidified Galloway lakes each year, they fail to nest there.

16. Another British bird about which there is growing concern is the dipper. Dipper territories in Galloway appear to be larger than normal, possibly indicating a shortage of food due to acidification of streams.

17. British areas of wildlife importance which may be susceptible to acid rain include the Dorset and New Forest heathlands, parts of the Weald, possibly the Brecks and the Bedfordshire Sands, some of the higher moorlands, the extensive Pennine grasslands and blanket bogs, almost all of Wales and much of upland Scotland. Although not yet subject to separate studies here, many British species have been shown to be highly susceptible to acid rain effects elsewhere eg pied flycatcher, bluethroat, willow warbler and reed bunting.

18. Many water plants are susceptible to changes in acidity. Acidification typically causes a decline in emergent and marginal species (eg bullrush and reed mace), while acidophilous species such as sphagnum mosses may become abundant. Overall the total biomass (ie the weight of organisms per unit area) may not be affected by increased acidity, but there is usually a marked decline in both the richness and diversity of species communities, which can be of significance for ecosystem function, nature conservation, amenity and economic purpose.

19. Appendix A is a list of acidified and threatened freshwaters in Britain.

20. It is established that dry deposited SO_2 significantly increases the corrosion rare of susceptible stonework, such as limestone and sandstone. Similarly, dry deposited SO_2 can corrode metals like carbon steel, zinc, copper and nickel, as well as damaging wood, paper, paint and plastics. Vehicles, we well as electrical devices containing copper, silver and gold, can also be corroded. Few studies have been undertaken on the effects of wet deposition on materials and it is very difficult to separate these from those of dry deposition.

21. In London, St Paul's Cathedral has lost 30 mm of its Portland stone in the last 250 years, but 22 mm of the exposed parts, such as the vases of the South Portico, has been lost in just 45 years.

22. In Cracow, Poland's historic buildings need to be cleaned every five years due to air pollution. In Holland, the cost of building repair arising from SO_2 is put at £6.8 m a year. In West Germany repairs to Cologne Cathedral run to £1.4 m. The Coliseum in Italy and the Acropolis in Greece are both seriously affected.

23. Recent evidence suggests that ambient concentrations of gaseous pollutants in Britain may cause yield losses to a number of sensitive cereals, grasses, root crops and vegetables. Unfortunately it is extremely difficult to design laboratory experiments which realistically reflect field conditions. On the other hand, the result of field experiments reflect a wide variety of environmental influences which are difficult to separate. However, it has been estimated that if pollutants reduce yields by as little as 10 per cent, the UK crop losses could be £200m a year.

24. The most likely cause of any British crop loss would appear to be synergistic damage from SO_2 and ozone. Synergistic effects can significantly lower the threshold of injury to plants. In the USA, where ozone levels are generally higher, the cost of reduced yields of wheat, corn, soya bean and peanuts from elevated ozone levels is put at $3.1 billion a year.

BRITISH EMISSIONS AND DEPOSITION

25. Acid rain is already widespread in Britain. The recent report by the Acid Rain Review Group (Acid Deposition in the UK, Warren Spring Laboratory, 1984) shows that Britain's rainfall is, on average, four to five times more acidic than natural "clean" rain (assuming a natural pH of 5.0). The report also shows that 70 per cent of the acidity is due to sulphuric acid and 30 per cent due to nitric acid.

26. In Britain most of the sulphur dioxide is emitted from power stations. In 1982 (the last year that figures are available), 57 per cent of the SO_2 came from coal and nine per

cent from oil-fired power stations. Power stations are also the largest single source of oxides of nitrogen (45 per cent). British sulphur emissions peaked in the early 1970s and have declined since then, due to industrial recession and increasing use of natural gas (which now accounts for 23 per cent of primary energy).

27. It is estimated that 80 per cent of the sulphur deposited in Britain comes from sources within our own country, while only 11 per cent is imported from abroad (three per cent France, one per cent West Germany, two per cent East Germany, the remainder from a number of other countries), and nine per cent comes from natural and "other" sources.

28. Britain is the largest emitter of sulphur dioxide in Western Europe, and it has been estimated that 77 per cent of its pollution is exported abroad. British emissions contribute 14 per cent of the sulphur deposited in Sweden, seven per cent of that deposited in Norway, and seven per cent of that deposited in West Germany, as well as contributing to a number of other countries sulphur depositions. In contrast Britain receives no sulphur from either Norway or Sweden. In Europe, only the Soviet Union emits more sulphur than Britain (six times as much), but most of this pollution falls within its own boundaries.

29. Direct comparisons of historical pH measurements must be treated with care. However, analysis of early data suggest that the acidity of rainfall in rural Britain in 1870 was about pH 5.0 ± 0.5 when sulphur emissions were 20–35 per cent of those today, compared to an average pH of 4.3 in 1980 (Acid Deposition in the UK, Warren Spring Laboratory, 1984).

30. Studies of the diatoms in sediments of Galloway lakes, such as the Round Loch of Glenhead, indicate that acid rain first became significant during the industrial revolution, around 1850, with inferred pH falling from 5.5–5.7 before then to a modern level of pH 4.7–4.8 today, including a marked increase since 1940. Forested and unafforested catchments show similar declines in pH (Flower & Battarbee, Nature **305**, p 130, 1984).

BENEFITS OF REDUCING EMISSIONS

31. It has been argued by the CEGB and others that there is a non-linear relationship between sulphur emissions and acid deposition, ie a reduction in emissions might not achieve a proportional reduction in acidity. However, the American National Academy of Sciences recently concluded that there is no evidence "for a strong non-linearity in the relationship between long term average emissions and depositions" in the United States (Acid Deposition. Atmospheric Processes in Eastern North America, National Research Council, National Academy Press, Washington DC, 1983). The report also notes that the evidence for a non-linear relationship in Europe is not well founded because of changing sampling and analytical techniques over the past 25 years. At the EEC Symposium on Acid Rain "A Challenge for Europe", Karlsruhe, September 1983, S. Beilke, the rapporter for the section on "Origin, Transport, Conversion and Deposition of Air Pollutants" concluded that "A rough linear relationship between emissions of SO_2 and NO_x and deposition of these gases, including their acidic reaction products, is also given for a large European area in the long term average (for example one year)". More recently, in December 1983, Dr S. B. Smith of the Royal Meteorological Society, in a summary of the presentations on "production, transformation, transport and deposition" to the 15th Consultative Council Meeting of the Watt Committee on Energy, also concluded that there is a linear relationship in Europe.

32. The SO_2 emitted into the atmosphere will come down either as SO_2 or as sulphate. As both dry deposition of SO_2 and the wet deposition of sulphuric acid have detrimental effects on the environment, substantial reductions in SO_2 emissions can only be beneficial. The only substantial difference a strong non-linearity might make, is that the sulphur would be more likely to be deposited closer to the source as SO_2.

33. There is great uncertainty about the reliability of current mathematical models predicting the deposition of acid pollutants and their precursors. It will take many years

to develop models that can predict with confidence the transformation and movements of atmospheric pollutants.

34. Many of the effects of acid rain and its gaseous precursors may only be reversible over a time scale of several decades, particularly damage to freshwaters, soils and forestry.

35. Although acid rain is not a new problem, in recent years the evidence of damage has increased substantially. If sulphur emissions continue unabated, this trend is likely to continue. Thus sulphur emissions must be reduced in the short-term rather than long-term to prevent further acidification and to begin the slow process of restoring the damaged areas. The reduction in sulphur levels cannot wait until further refinements of the mathematical models.

COSTS

36. Within Europe there is considerable support for a Draft EEC Directive which would require member states to reduce SO_2, NO_x and particulate emissions by 60 per cent, 40 per cent and 40 per cent respectively. The reductions would be based on a reference year of 1980, and would have to be completed by 1995. The Draft Directive applies to all plant larger than 50 MW. There appears to be little information available on the number and type of plant that would be affected. Therefore this discussion is restricted to the cost to the CEGB system of meeting the Draft EEC Directive.

37. Sulphur dioxide emissions from electricity generation can be reduced by:—
(*a*) Reducing electricity demand
(*b*) Using coal and oil with a lower sulphur content
(*c*) Cleaning out sulphur before, during, or after combustion
(*d*) Introducing non-polluting electricity sources.

38. Power stations take of the order of 5–15 years to build, and operate for 25–40 years. Coupled with the present overcapacity, few new power stations are needed in the next 10 years. This limits the short-term impact of new non-polluting stations, which in turn necessitates SO_2 "scrubbing" in existing power stations. Due to the long lead-time for the commissioning of nuclear power stations this option is not a realistic alternative to desulphurisation in the short-term. Generation of electricity by nuclear power has a number of other, extreme, environmental, social and economic problems.

39. Friends of the Earth commissioned Dr Mark Barrett of the Open University to undertake a study of the cost of reducing the CEGB's 1980 sulphur emissions by 60 per cent by the year 1995, in line with the Draft EEC Directive. The study was based on the application of established desulphurisation technologies (Wellman-Lord) to the CEGB system. Several assumptions were made about the development of the electricity system in Britain. These are extremely conservative, and largely follow those of the CEGB's own scenarios (see below). The net effect is that they may well over-state the costs.

40. It was assumed that power station coal has a specific thermal content of 23.8 GJ/tonne and a sulphur content of 1.5 per cent by weight.

41. Three different scenarios for sulphur emissions in the year 1995 were investigated:—
(*a*) *CEGB's "Orthodox" Scenario*—the emissions produced as a result of the CEGB's central scenario for future electricity demand (scenario C).
(*b*) *Low Sulphur Scenario*—the same CEGB scenario C modified by fitting flue gas desulphurisation (FGD) to 22.2 GW (out of a total of 55 GW) of CEGB's plant to achieve about 60 per cent reduction in 1980 SO_2 levels by the year 1995. 18.6 GW of coal plant would be retro-fitted with FGD, mainly to base-load plant and generally that means all plant built after 1970. 2.6 GW of oil stations would be converted to coal and fitted with FGD at the same time. FGD would also be fitted to 1 GW of new coal plant.
(*c*) *Low Sulphur with Electricity Conservation Scenario*—the CEGB's scenario C modified by desulphurisation as in the Low Sulphur Scenario (above) and an

electricity conservation programme which reduces electricity demand in 1995 by five per cent as compared to the CEGB's scenario C. This does not assume a substantial *energy* conservation programme, for example, by substituting other, more appropriate, energy sources for electric space heating.

42. There are two reasons for adopting a "conservation" option. Firstly, it is cheaper than generating electricity and controlling the pollution that results. Secondly, as electrical appliances have a much shorter life than power stations, improvements in efficiency can be achieved over a shorter period. As oil generation becomes increasingly expensive in the 1990s, a conservation programme will help to keep down costs and limit the need to burn more coal. Conservation thus reduces the costs to the consumer whereas desulphurisation increases energy consumption slightly, and produces waste materials.

43. The five per cent reduction in electricity demand (for details see the Council for the Protection of Rural England's evidence to the Sizewell Inquiry) is assumed to arise from a mix of measures such as increased efficiency in domestic appliances, more efficient industrial motors and better lighting. For technical reasons it ignores the very substantial savings that would arise from better insulation of buildings that presently use electric heating.

44. The CEGB's scenario for future power station construction assumes that only one new power station will become operational by 1995 (1 GW of coal station). However, some 11 GW of coal stations are under construction during the period 1990–1995 and in the desulphurisation scenarios extra capital costs will be incurred even though the stations do not become operational. This results in an unrealistic bias against desulphurisation.

45. Although some sulphur can be removed from coal by washing before combustion, this technology has *not* been included in our model. We have also not included in our model the use of fluidised bed combustion (FBC), although it is probable that the present uncertainties about its development could be resolved by the mid 1990s when new coal stations might be built. Successful development of FBC would be highly significant.

46. There are two types of process which remove sulphur after combustion: regenerable and non-regenerable. This model assumes that the Wellman-Lord process of FGD is used. This is regenerable and produces SO_2. Little solid waste is produced. It is not certain that Wellman-Lord technology would, in fact, be the cheapest, but it is the one best known to the CEGB.

47. One of several alternatives which has been operated commercially is the MgO process. The capital costs are similar to the Wellman-Lord but lower variable costs mean that the cost per unit of electricity are about 27 per cent less. Another regenerable process, called Sulph-X has desulphurisation costs close to those of the MgO process, but is only at a pilot scale of development at present. Both the Wellman-Lord and the MgO process generate SO_2, which produces saleable sulphuric acid.

48. For the lower sulphur scenario (b), the total costs of construction and operating the CEGB system increase by 3.2 per cent, while for the electricity conservation scenario the total costs increase by 2.6 per cent.

49. If it is assumed that the price of electricity to the consumer reflect the costs of production, it can be concluded that the increase in price of delivered electricity due to reducing sulphur emissions will be between three and four per cent. This is likely to be a ceiling figure since the highest figures for capital and running costs of the Wellman-Lord process have been assumed. For the electricity conservation scenario it has been assumed that power station kept operational and built remains unchanged: this clearly would not be the case if demand were lowered. Furthermore, the bulk of the investments in conservation has occurred by 1995, yet the benefits are not assumed to peak until 2000.

50. From our research it is safe to conclude that meeting the EEC Directive for sulphur emissions in the CEGB system would result in increased costs to the consumer of four per cent or less. This is well within the average electricity price rise in recent years (4.8

per cent for domestic users and six per cent for industrial users average per year between 1974 and 1982 in real terms).

APPENDIX A

ACIDIFIED AND SUSCEPTIBLE FRESHWATERS IN BRITAIN

The following is intended to give an indication of the widespread nature of freshwater acidification in Britain. It is *not* a comprehensive list.

Heaths and ponds in Surrey
Freshwaters in the New Forest, Hampshire
Numerous Streams in the Peak and Lake Districts
Loch Long
Loch Ard
Clatteringshaw Loch
River Fleet
Loch McAterick
Loch Doon
Loch Dee
Buchan Burn
Round Loch of Glenhead
Round Loch of Dungeon
Loch Neldricken
Loch Valley
Lake Elan
Lake Bala
Loch Fleet
Loch Grannoch
Loch Enoch
River Twyi
River Teifi
River Dyfi
River Glasyln
River Dee
River Alwen
River Conway
River Severn
River Wye
River Duddon
River Esk

Examination of witnesses

MR C. ROSE, Pollution Campaigner, DR M. BARRETT, Consultant, Earth Resources Research, and DR C. HOLMAN, Information Officer, Friends of the Earth, called in and examined.

Chairman

89. Good afternoon, Mr Rose, you are leading the representatives of the Friends of the Earth this afternoon? Would you like to introduce your colleagues?

(Mr *Rose.*) On my left is Dr Claire Holman. She is an atmospheric chemist by training, she has researched on the long range transport of ozone in the lower atmosphere and she has worked for Friends of the Earth for a year or more. Dr Mark Barrett on my right is a consultant working for Earth Resources Research Ltd. He is also attached to the Open University. He is an energy analyst who has prepared evidence for the Sizewell Inquiry on electricity conservation and combined heat and power schemes. He also has conducted a lot of energy modelling. For myself, I am by training a wildlife ecologist and I am employed as countryside and pollution campaigner of Friends of the Earth and have conducted research previously on air pollution and its effect on lichens.

90. Thank you very much. First of all, thank you for coming to give evidence before us and for submitting your paper

[Chairman *Contd.*]

beforehand. I am not quite sure how we are going to proceed this afternoon. There is a possibility we may be dragged downstairs on a series of divisions but we have to take them as they come, and also I hope we are not too "tetchy" as a result of having been up for the best part of 24 hours, so bear with us. I would like to turn to your paper, if I may, and first ask a general question. You mention the effects of NO_x and ozone almost in passing. The main preoccupation of your paper seems to be with SO_2. How important do you regard NO_x and ozone in ecological terms?

*(*Mr *Rose.)* We do not know. We took the decision to concentrate on sulphur dioxide because most seems to be known about that, and the research that we commissioned from Earth Resources Research was looking into the sulphur economy, the sulphur budget in the energy economy and the role of sulphur dioxide, in so far as we could in reviewing the evidence, in contributing to acidification. Obviously we have seen evidence from people such as the Department of the Environment Warren Spring Laboratory which indicated that something like 70 per cent. of the acidification of British rain came from sulphur as opposed to from nitrate. We would like to have commissioned work ourselves on NO_x but we have not yet been able to get the funds together to do that.

91. I do not know whether other Members of the Committee will agree with me but on the basis of the evidence we have received so far and from what we have seen on our recent visit to the Black Forest, there seems to be growing doubt as to whether or not acid rain in itself is the cause of forest damage. One accepts that emission of sulphur converts to sulphur dioxide and sulphuric acid and we have acid rain but in so far as the damage that is being caused is concerned, there seems to be a growing body of opinion that it may be caused more by NO_x and ozone and the effects of sunlight upon that, a photochemical process. Would you like to comment on that evidence that seems to be emerging?

*(*Mr *Rose.)* We are convinced from the evidence we have been able to glean that sulphur dioxide is very important in affecting fresh water, in its effect on fish, rivers and lakes.

92. I would like to come to that later. I am talking now of the effect upon trees and forests and vegetation.

*(*Mr *Rose.)* I think we would largely accept that.

93. Then you would accept, I suppose, that if that is the case NO_x and ozone control are important matters to be considered?

*(*Mr *Rose.)* Yes, we accept that they are important.

94. There is no mention of it in your paper. That is why I was raising the point with you in this way. It is a matter which seems to us to be of importance and it does not seem to be referred to in your paper. Dr Holman, I was told you were carrying out research in this field. Could you help us further?

*(*Dr *Holman.)* I am not carrying out research in this field. I have a PhD in atmospheric chemistry and it happened to be on the subject of ozone. I am a chemist by profession. I would like to reiterate what Mr Rose has just said, in terms that we have obviously limited financial resources. As the evidence when we commissioned our research seemed to indicate sulphur dioxide was the most important pollutant in terms of fresh water pollution, we decided to concentrate on that aspect. Since that time we do agree with you that ozone and oxides of nitrogen are important pollutants and we do feel they should be controlled as well as sulphur, but because all our research is mainly on sulphur dioxide we have concentrated in our paper on that pollutant.

Mr Taylor

95. Could I ask a supplementary, which I think flows from your question, Chairman. Let us accept for the moment that sulphuric acid, nitric acid and photochemical processes may all be regarded as adverse to vegetation, and let us leave on one side for a moment which is the worst villain. One of the very clear things which emerged from our visit to the Black Forest was that the real damage seems to have been suffered by the pine trees, the needles. The deciduous trees, if they were a little out of sorts it was scarcely noticeable. To me as a non-chemist, non-botonist, just drawing "Peter Simple" conclusions, the deciduous tree has a large leaf surface and is very dependent upon that large leaf surface in its life cycle, and it seemed to me that the deciduous would have been wide open to be brutalised compared with the fir tree because it was more vulnerable in that way. I am a non-expert. Have you a reaction to that? Have you any thoughts on that for me?

[Mr Taylor *Contd.*]

(Mr *Rose.*) I am not a biologist. I cannot claim to be an expert on the leaf area of conifers and of deciduous trees. The leaf area of conifers is actually very large as you have the tree almost covered by pine needles or other needles. They are also on the tree for a very much longer length of time than the leaves of a deciduous tree, which fall, so they come onto the tree in generations; they come on all within one year, whereas the pine needle might be there for very much longer than one year. That may have something to do with it.

Chairman

96. One of the matters I had in the back of my mind when asking you this question was the way in which your paper was presented to us. If you turn to paragraph 11, you talk of acidification of lakes due to acid rain. In the next paragraph where you are dealing with tree damage in the Black Forest in particular, you very carefully use a different term "air pollution", then you refer in paragraph 14 to wildlife being threatened by acid rain and 15 the osprey and 17 the dipper. Then on paragraph 17 you deal with acid rain in Dorset and the New Forest heathlands. Now, someone reading those paragraphs consecutively and more rapidly, although you use the term "air pollution" in paragraph 12, you are still talking about acid rain because you have not drawn the reader's attention to a possible distinction that there may be. I think it is true to say that when we were in the Black Forest we noticed the lichen was flourishing in areas which are sensitive to acidity where the trees were adversely affected by some kind of pollution or other. That is the thing which lead us to our conclusion regarding ozone and other things I was talking about. I hope you do not mind that account?

(Mr *Rose.*) Could I respond?

97. Yes?

(Mr *Rose.*) Paragraph 5, just under the summary at the start, we are aware of that problem. Obviously, we hope not to mislead anybody by the way we present the evidence. We do refer to the problem of wet and dry deposition as well. As to the question of the lichen, I have not been to the Black Forest, I understand that Dr Francis Rose—who is no relation of mine—a lichenologist in this country is impressed by the damage to the lichen or absence of lichen in those areas. It is a species which is particularly susceptable to sulphur dioxide and there are many lichens which are acidophilous which are flourishing.

Mr Roberts

98. The thing that seemed to impress me was the evidence that it was exposure to sunlight, to light as well as pollutants, that was causing the problem. So, it was not just the acid, it was perhaps this photosynthesis effect. What would you say about that?

(Mr *Rose.*) I think if ozone photochemical effects are involved, that is very likely, we are not claiming that sulphur dioxide alone is responsible for what is happening in the Black Forest.

Chairman

99. As you have not carried out any research into this for fund reasons, I do not think it would be fair to press you further on that. Perhaps we could turn to an area in which you have concentrated, namely the effects of acid rain. Now in paragraphs 8 and 9 of your paper you point out that the acidification of the Scandinavian lakes has been continuing for decades, yet we understand the SO_2 emissions are falling, therefore, can you help us as to why that may be, why the acidity is increasing if SO_2 conditions are falling?

(Mr *Rose.*) The falling acid deposition is relatively recent; however, some of the processes may be accumulative processes in the same way as erosion may be. If you are talking about the leaching of chemical bases through an ecosystem, that may be an accumulative process, thus even though the input of acidity may be reduced, the effect may still be to render the ecosystem more acid. We are not claiming we have done primary research into this, this is our result of looking at other studies people have done. The research which we have commissioned is on energy modelling.

100. In paragraph 9 in particular you talk about the effects of acidity upon fish life and you say in particular that the native brown trout cannot survive the combined effect of acidity and elevated concentrations of aluminium. The evidence we received from the scientists of the CEGB was that the disappearance of fish had to do more with the absence of calcium than it had to do with the presence of acidity, in other words fish could tolerate a high degree of acidity in the water if there was a lot of

[Chairman *Contd.*]

calcium there, it is when there was a drop in the amount of calcium that the fish began to die off. Would you agree with the evidence or not?

*(*Mr *Rose.)* I am sure that if that is what they say from their experiments, that is actually the case. I have heard scientists, I think it is from the Freshwater Biology Institute or the Institute of Terrestrial Ecology in Scotland, relating that rises in aluminium levels interfered with the hatching of fish eggs, trout eggs and also that when they have looked at lakes, where these lakes are in spray zones of the sea for example, a much higher concentration, raising their acidity does not seem so important.

101. There does seem to be a suggestion that a lot depends on the nature of the ground or soil in the catchment area of the lake and your reference to aluminium seems to be varied where the acid leaches out aluminium from the soil and takes it into the lake and then the aluminium has a very toxic effect on the fish. There does seem to be that correlationship. What we are trying to do is test evidence we received from one witness by putting it to other witnesses. I wanted to see what your view was?

*(*Mr *Rose.)* One other important thing about aluminium is where you have a high degree of peat in the water and soil then some of the aluminium gets chelated and it is not available to the fish whereas if you have a mineral soil it will be available.

Mr Roberts

102. What does chelated mean?

*(*Mr *Rose.)* Combined with some organic matter from the soil.

Chairman

103. Could I ask you how much weight you attach to arguments that forestry management practices are a principal cause of acidification of lakes? In other words, if you plant the sides of a lake with a lot of conifiers the effect of that could well be to increase the acidity of the water in the lake.

*(*Mr *Rose.)* Again I have been convinced by talking to people in the Welsh Water Authority that that may well be happening in Central Wales for various reasons, but I would not blame forestry. I would blame air pollution and say that the effect of forestry was to exacerbate the effects of air pollution.

104. From your studies, which species of trees in the United Kingdom do you regard as most at risk from acid rain or dry deposition?

*(*Mr *Rose.)* We have not any evidence of actual damage to trees in Britain but presumably the same species—fir and some of the pine trees—which have been reported to have been damaged in Europe and which are growing in the same conditions. We do not have a detailed answer to that.

Mr Roberts

105. Why do you think there is not the damage in Britain that there is in Europe?

*(*Mr *Rose.)* It is to do with the climate probably.

*(*Dr *Holman.)* I am not sure how much the Forestry Commission and other interested bodies have actually investigated damage to trees in this country and unless you look for the damage you are not going to find it. We do, however, have a different climate from that of Central Europe and this was brought out by the CEGB on Monday. We have a maritime climate rather than a continental climate and it might well be the case that a lot of the damage generally is at higher altitudes and we do not have the mountainous regions that they have in Central Europe, so our conditions are very different both in terms of climate and topography. It is, possible, therefore, we are not experiencing that damage but it is of the utmost importance that we actually do look to see if there is any damage being done.

*(*Mr *Rose.)* If one were looking for damage and if the mechanism was of acid emissions, say mist or cloud, many of the conifers growing in Central Wales and parts of the Lake District might be affected. If it is a soil-induced mechanism then presumably one would be looking for old-established semi-natural woodlands. We are waiting to see the Nature Conservancy Council's opinion on this but many nature reserves might be at risk because they do have natural soil structures, whereas West German forests are largely natural forests, like the Black Forest, our forestry plantations are not natural forests and have quite different soils.

Chairman: If I may add a comment, not a question, on what you have just said, some of the evidence we received in Germany was

[Mr Roberts *Contd.*]

that the mists are ten times as acid as the rain itself and, therefore, required further study, and the CEGB when they gave evidence and we asked them questions about this accepted that the mists and fogs can be much more lethal than the rain itself.

Mr Roberts

106. What about the amount of pollution that we do not import compared with the amount that is claimed to be imported into, say, West Germany, because of our position and the prevailing winds? Is it because we are not getting such pollution that we are not seeing the same amount of damage and it is only a matter of time?

(Mr *Rose.*) We do not know. It is true, of course, that we export proportionately much more of our pollution.

(Dr *Holman.*) We export in Britain 77 per cent of our sulphur emission and most of the sulphur dioxide deposits in Britain are from our own sources, I think 80 per cent, so in effect we are to blame ourselves for any damage that can be seen in Britain. But in terms of whether West Germany is a net importer or exporter of sulphur dioxide I could not tell you off the top of my head. I can supply the figures.

Mr Roberts: They claim they export 50 per cent of what they produce and import 50 per cent of what falls on them!

Chairman

107. I did not want to come to the export and import problem for the moment. I wanted to work through your paper on the effects of the ecology, but as you have mentioned the figure of 77 per cent perhaps we might dispose of that now. You refer to that in paragraph 28 of your paper and then you give us something of a breakdown. I say "something of a breakdown" because you say our contribution is 14 per cent of sulphur deposited in Sweden, 7 per cent in Norway and 7 per cent in West Germany. Those three figures only come to 28 per cent and we have still got a long way to go before we reach 77 per cent, so I wonder where you collated the remainder of your evidence?

(Dr *Holman.*) They are just examples of where some of our sulphur goes but obviously it goes all over Europe in different proportions. They were taken out because Sweden, Norway and West Germany are those countries which have been most vocal about the effects of acid rain over the last few years.

(Mr *Barrett.*) I think actually you are misreading the percentages. What it is saying is that 77 per cent of UK sulphur emissions travel abroad and that of the sulphur deposited in Sweden 14 per cent of it comes from the UK, so they should not add up to each other necessarily.

Chairman: Thank you, I am grateful for that.

Mr Chapman

108. On that point, do these figures take into consideration the amount of sulphur dioxide that must surely fall on the seas around Britain?

(Dr *Holman.*) The figure of 77 per cent is that which leaves the shore of Britain, so part of that 77 per cent will fall in the North Sea. However, you have to take these figures with a slight pinch of salt in that the models which estimate these figures are only accurate within a factor of two.

Chairman

109. What is your source for these figures?

(Dr *Holman.*) Our source is a combination of the Warren Spring report by the Acid Rain Review Group, and a paper published in Ambio by Nicholas Highton and Professor Chadwick of York University.

Mr Chapman

110. I am not in any way wanting to minimise the importance of those figures or the gravity of the problem but I am right in saying that a considerable amount of the emissions of SO_2 and, indeed, the NO_x's actually falls on the sea? We might export 77 per cent of our SO_2 but that 77 per cent is not exported to other countries, a lot of it falls on the sea?

(Dr *Holman.*) A certain proportion of it will. How large that proportion is I do not know.

Mr Chapman: Just for the record, we need to check it, that of the total amount of emissions that leave the United Kingdom 50 per cent at least falls on the seas and principally, I suppose, the North Sea but we will obviously check that.

Mr Roberts

111. It is recycled in 200 million years, though.

[Mr Roberts *Contd.*]

*(*Dr *Holman.)* I would be surprised if the figure was that high, personally.

*(*Mr *Rose.)* It is something I have been misled by myself before. I think Britain's net sulphur depositions are very large because we emit a lot of sulphur. I think if you work out the relationship between our import and export of sulphur our export is 23 times larger in tonnage terms than our import which is deposited here.

Chairman

112. One of the things that has also concerned us is the possible effect of acidity upon the fabric of our buildings and so far we have not been helped a great deal in the evidence we have been given. Certainly in this country there seems to be a lack of knowledge. You assert in paragraph 20 that "it is well-established that the dry deposited SO_2 significantly increases the corrosion rate of susceptible stonework, such as limestone and sandstone." Can you tell us what evidence you may have available to you that has led you to that conclusion and can you quantify it in any way?

*(*Dr *Holman.)* It is very difficult to quantify it. I do not know in what sort of terms you want me to quantify it. There have been various economic analyses of the cost of repair of buildings. You have been to Cologne Cathedral and presumably you have some figures for the cost of the repairs to that building.

113. Yes, the Germans were quite clear as to the effect that sulphuric acid and sulphur depositions were having upon Cologne Cathedral. It is when we start asking questions about buildings here that we find there is not quite the same depth of knowledge and that is what we are seeking.

*(*Dr *Holman.)* I understand that quite a lot of work was done in the Sixties, especially in the Birmingham area, on the sulphur dioxide levels in the atmosphere. They were a lot higher there at that time, so they are not directly comparable with the levels of sulphur dioxide in the atmosphere now. In terms of more recent work which is more relevant to the discussion today, I am not aware of any studies being done other than the ones that the CEGB mentioned in their submission on Monday.

114. You have heard what they told us. They said they had been carrying out research for decades on the effect on metals and they knew a lot about that but only two years upon stone work.

*(*Dr *Holman.)* Yes.

115. We wondered whether you knew of anybody else who may be carrying out experiments who could give us information?

*(*Dr *Holman.)* Work has been done in other countries as well. The Working Group under the Geneva Convention looked at the effect to materials and there is a considerable amount of evidence in the documents they produced, from all over the world. I do not know whether you have seen the document?

116. We are concerned with the level of pollution primarily in this country and our atmosphere and the effect it is having on our buildings and what is the cost of that or potential cost of that to the country in havng to make good this damage in the next two or three decades. We want to put that on one side of the equation to compare it with the cost of requiring somebody to stop this pollution. This is the evidence we are seeking.

*(*Dr *Holman.)* I do think you can extrapolate some of the evidence from other countries in terms of damage to materials because many of the materials are similar to that used in other countries. I understand in recent years the City of London has been very worried about the effect of air pollution on buildings in the City and they have introduced an order to require all oil that is burnt in the City to be of a low sulphur content and that was to protect buildings such as St Pauls.

117. Yes, St Pauls was mentioned to us particularly by the CEGB and you mentioned that in paragraph 21 to give us the rate of loss to the stonework there. You then go on to talk about Cracow which needs to be cleaned every five years due to air pollution. When you talk of cleaning, do you mean the kind of cleaning we have carried out since we had a Clean Air Zone or do you mean a different kind of cleaning? Is this soot depositions we are talking about or the effects of acidity?

*(*Dr *Holman.)* It will include the effects of this type, which is the reason why this building is being cleaned. It will also include repair to damage that has been caused by several pollutants.

118. Air pollution in Cracow is far in excess to air pollution anywhere else in Europe?

*(*Dr *Holman.)* That is true.

Mr Alexander

119. Can I ask a question on paragraph 21, I am not sure as I read it you are comparing like with like, you say: "St Paul's Cathedral has lost 30 mm of its Portland stone in the last 250 years...", then you go to the exposed parts in 45 years. How much has it lost of its Portland stone in the last 45 years?
(Mr *Rose.*) We do not know. We do not know exactly.

120. I am not a scientist and I went to school a long time ago, can you tell me in inches how much 30 mm is?
(Dr *Holman.*) An inch—25 mm would be an inch.

Mr Jones

121. Can I ask you about the effects on wildlife? In your paragraph 14 you are talking about the breeding conditions for the natterjack toad, at what sort of Ph levels does the breeding cease? When does it become too acid?
(Mr *Rose.*) I think it is 3.6 it ceases altogether and the success of hatching of sporn, I think it is the first stage of cell division, success in that seems to drop off rapidly about 4 or 5. I could supply you with the exact figures.

122. Coming on to your next paragraph about ospreys, you were talking about ospreys prospecting the acidified lakes and not nesting there. Is it not one of the characteristics of ospreys they do not settle on the lakes they might have prospected? They might have prospected non-acidified lakes and failed to settle.
(Mr *Rose.*) I think this refers I think to the Nature Conservancy Council and other ornithologists not working for them in Galloway area. It was their opinion that they were surprised that ospreys were not resting in the area of granitic lakes in Galloway. It was not because of a factor of lack of fish, that was supposition, we do not claim there was any proof.

Mr Alexander

123. There was one question arising out of mine, we have had a Clear Air Act since 1956, has the expense of that Act made any difference at all to the rate of corrosion on St Paul's Cathedral?
(Mr *Rose.*) I do not know but I should imagine it has slowed it down.
(Dr *Barrett.*) The basic problem of building, it is "O" level chemistry, calcium carbonate and limestones like that are absorbed by acid, you have to determine the rate of solution of these. Historically, buildings in any of these different parts of the United Kingdom offer such long time spans, it is a very difficult thing to quantify.

Mr Roberts

124. Do natterjack toads survive in areas where there is sea water easier because of the effect of the acid?
(Mr *Rose.*) I do not know exactly. I think there is a pool in Norfolk where the Nature Conservancy Council have experimentally limed natterjack breeding, which is a coastal breeding site. I think it is dune slack. They do breeding studies on the Ribble, Mersey and the Dee.

125. They breed in my constituency that is why I am asking, I am wondering if they are under threat?
(Mr *Rose.*) I do not know.

Chairman

126. I wonder if we could move on, we have dealt with buildings, forests, wildlife, could we go to your paragraph 23 where you talk about or give us figures for the possible crop losses in this country or the savings that could be made if pollutants were reduced. I am just wondering how valid that is as a statement? You say that there is no evidence of crop damage and then you go on to postulate figures as though there were?
(Dr *Holman.*) We do not actually say that, we do say if pollutants reduced yields by as little as 10 per cent, the UK crop losses could be 200 million pounds a year.

127. We do not know they reduce it, so what?
(Mr *Rose.*) That figure was from an Institute of Terrestrial Ecology Scientist who is working on this subject, who is discussing it. I think he thought it was within a possible review of reductions there might be. In laboratory studies it is possible to show how high SO_2 levels can affect the

[Chairman *Contd.*]

growth of crop plants but it is the difference between the laboratory and the field conditions which are enormous.

128. Would it surprise you to know that we were told that an increase within certain tolerances of the amount of sulphur in the atmosphere in fact increases crop yield because sulphur is a natural ingredient of plant life and, therefore, you may be replacing the differential and therefore up to certain levels you can be benefiting your crops?

(Mr *Rose.*) It would not surprise me for one reason, because it is true that in America there is some evidence that in some areas soils naturally may be sulphur-deficient and sulphur deficiency is very rare in British soils naturally. If you raise the levels of nitrogen, phospherous and potassium, which are also plant nutrients, and do not raise the level of sulphur you might induce an artificial demand for sulphur, so that the crop might be sulphur limited and that might be what some agriculturists mean when they say if air pollution is reduced crop yields may be reduced.

129. I can see it is very difficult in laboratory conditions to simulate open-air field conditions. I am not sure we will ever get to the bottom of that, although I believe the CEGB are carrying out extensive experiments on this and are trying to simulate these conditions as best they can but I need scientists to tell me whether or not they are doing it sufficiently precisely enough to be valid.

(Dr *Holman.*) There is a large amount of research that has been going on in universities and in the Institute of Terrestrial Ecology on the effects of air pollutants, and I hope you noticed that we used the term "gaseous pollutants" and not "acid rain" in this respect because ozone is thought to play an important part in reducing crop yields. There is a lot of evidence in the States about the economic loss. I have seen various figures, up to about $4 bn per year in reduced crop yields. Because of the evidence that has come from the States, both on the effects of sulphur dioxide, oxides of nitrogen and ozone, and the difficulty in actually determining and measuring the reduction in crop yields when they are fairly small, of the order of 10 per cent, I think this costing of £200m is quite important because it could well be happening and we would not know about it. If it was a 50 per cent reduction of yields it would be so obvious we would know about it and that economic cost would be put into the cost benefit analysis. But I think there is enough evidence to suggest there is quite likely to be a reduction in crop yields and, therefore, we should consider it as an important effect.

Mr Alexander

130. I find it difficult to reach a conclusion on what you are trying to say in paragraph 24. I confess that I am not a scientist. Can you, first of all, tell me what synergistic means?

(Dr *Holman.*) That means that the additive effects of both pollutants is greater when they are both present rather than the effect singly.

131. We have heard a lot of evidence, as you know, that ozone might be more significant than SO_2. How does that view appear, if at all, in the conclusions you reach in paragraph 24?

(Dr *Holman.*) I am not quite sure I understand the question.

132. Does paragraph 24 indicate that that is probably the case?

(Dr *Holman.*) I do not think you should take any of the paragraphs in that section in isolation. What we are trying to show is if you take all the evidence that is available on all the different ecosystems and the different environments, there seems to be enough evidence that gaseous pollutants and wet deposition pollutants together are causing a huge threat to our environment. We have already said there is a reason why we are concentrating on sulphur dioxide but we are aware of the importance of ozone and do feel there should be some policy in terms of reducing hydrocarbon and NO_x emissions to reduce the ozone levels in the lower atmosphere.

(Dr *Barrett.*) I do not think it should be taken as a general conclusion in paragraph 24. Rather what it is saying is that it is acid, fullstop, whether nitric or sulphuric acid, that is damaging. Maybe with some trees it is ozone; maybe with crops it might be ozone; maybe with fish in fresh water lakes it is just acid again, fullstop, which is changing the ion concentration. So, the pollutant has an effect but the detriment, the damage in each sector will not be equal according to each pollutant. They will not have the same effects.

Chairman

133. The most important part of your paper, if I can put it that way, in the sense that it gives us something we have not received from anybody else, is your cost benefit analysis. I wonder if we could spend a little time on that. Perhaps you would like to state orally exactly what your views are and your conclusions in this particular field?

(Dr *Barrett.*) Perhaps I could say a bit on this. It is not something I have done a lot of work on. It seems to me the general problem is that one can probably estimate the costs of sulphur abatement, either by conservation or scrubbing in the power stations, to, say, within 20 per cent or maybe even worse than that, given the uncertainties about future fuel prices and so on. When it comes to the value of the damage done by air pollution, it seems to me we are in terms of plus or minus 100 per cent, and I do not think there is a neat solution which the scientists or the economists can come to in this respect. At the end of the day it is going to be à matter of judgment. In my view, the cost benefit equation, the way one decides about it, is going to be quite heavily influenced by the magnitude of the known costs. If they are very high one would be faced with a much more difficult decision than seems to be the case. In my view, the cost of abatement would be quite small as compared with the total throughput of the energy economy in the country, for example.

134. You accept that if we, as a nation, were to set about the reduction of sulphur and nitrogen oxides from the atmosphere we would have to tackle the power stations as the prime cause of the emission of these pollutants; and if there was a requirement by Government that they reduce the emissions to an acceptable degree, say within the terms now being discussed by the European Commission, it would inevitably lead to an increase in the price of both domestic and industrial energy. Various figures have been given to us. I wonder whether you would like to comment upon that and what figures you feel would be acceptable in terms of the British public and of industry, the increase in energy costs in order to deal with this problem?

(Dr *Barrett.*) The first thing to say is that our approach on the abatement side of the equation has tried to be a preventive one in that rather than throwing lime into lakes when they are being acidified, you try to stop the sulphur getting there, and rather than trying to scrub sulphur dioxide from station chimneys, you try to reduce energy demands, in that the reduction of energy demand and conservation reduces any pollution upstream in the energy system, whether it be radioactive or chemical as in the case of acid rain. It seems that going for the sort of targets which the EEC are proposing in their directive would lead to something of the order of a 3 or 4 per cent increase in the real price of electricity to the consumer over the next 10 or 15 years. When one puts this into the context of the projected real price increases of electricity due, for example, to increases in fossil fuel prices over the next 10 years, it is very small. In a word, to reduce pollution by 60 per cent in 10 years it is 3 or 4 per cent, whereas the real price rise of electricity is a factor of at least five times larger than that. But whether 19 m electricity consumers would consider it worthwhile having their bills go up by 3 per cent rather than suffer acid pollution is not a question I can really answer.

135. That is why someone will have to show a direct correlation between the emissions and the damage that is being caused and that is why we have been asking all the questions that we have been, because there is no point in spending £2 or 3 bn on making adaptations to the power stations and increasing the price of fuel for everybody only to find we got it wrong and that the cause of the damage is something other than sulphur dioxide or whatever it is we have taken the trouble to reduce or eliminate, and this is part of our concern.

(Mr *Rose.*) Taking all the evidence together, we are convinced that it amounts to showing that there is a good correlation. We admit that it is impossible to pass over, stop and account for every possibility. Friends of the Earth take the view it is likely to be more expensive to act later rather than sooner. Some of these things have been damaged. We are impressed by the findings of people such as the Organisers of the World Conservation Strategy who asked the public in a Mori poll whether they would put an extra penny in the pound on income tax for protecting the environment and 53 per cent of the people said yes and that is a tremendous amount—more than a couple of per cent on electricity prices, of course.

(Dr *Barrett.*) The converse view is if we try to decide not to try and reduce acid pollution and we are wrong; in 10 years

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time if we look back and think we could have avoided this by an increase of 4 or 5 per cent in our energy prices, it seems to me the guarantee if you like is fairly cheap even though one cannot quantify the value of the effect caused by acid pollution to any great precision.

Mr Alexander

136. You have obviously taken the view you are aware that various distinguished bodies, not least the Select Committee, are by no means as certain and that the Royal Society is spending many millions of pounds to find out, do you not think it would be wise to wait rather than ask for this recommendation to be put into effect?

(Mr *Rose.*) No, I do not. I think we are in the same position, I believe, as we were some time ago, perhaps with the debate about lung cancer and tobacco. There comes a point when taking the evidence together we think it is time to act and this is the view we have taken. I think what the Royal Society are doing I find peculiar in some ways. I understand they are looking at acid, I understand how the thing came about but not looking at acid in Britain which a lot of people are concerned about—very concerned about.

Mr Chapman

137. They are undertaking their inquiry in relation with the equivalent Royal Societies in Norway and Sweden and presumably at the instigation of Scandinavian countries because of the alleged damage to their ecology by pollutants coming somehow from the United Kingdom, is that not the raison d'etre of the Royal Society's inquiry?

(Mr *Rose.*) I think the damage is substantiated, the alleged bit certainly some of the pollutants go there and we think that the fact we know some of the pollutants go there and all the pollutants which are there are causing damage, I do not think it is an excuse to not take action. Our pollutants are going into a polluted environment, the fact we might not be able to put off our own bat and stop all the pollution that is ending up in the environment is not a reason for us not to take action.

138. You would agree whatever action should be taken—and you clearly believe action should be taken—it should be a transnational application, in other words, would it be wrong of us to try and do something in isolation, perhaps a Joint European Programme?

(Mr *Rose.*) No, we believe if necessary Britain should, if necessary, take unilateral action. It should not be contingent on getting agreement of every country which is involved in this form of pollution. One could expand that argument to include the USSR, which is impractical, although through the Geneva Convention on Transboundary Air Pollution they are involved anyway.

Chairman

139. A few moments ago you mentioned you thought one of the more positive ways of approaching this problem would be to seek means of reducing energy demand and that way you would reduce your emissions. In what particular ways would you recommend that this would be reduced? Is it heat-conservation planning of buildings or alternative forms of heating? Would you expand on that?

(Dr *Barrett.*) Yes. First of all, I would just, if I might, respond to an earlier point?

140. Yes?

(Dr *Barrett.*) When looking at the time scale of the application of, for example, flue gas desulphurisation and running parallel with that, the sulphur research programme looking into the detrimental effect of acid pollution, one might consider the option of getting a programme going so as to meet the EEC directive in that large amounts of money will not be spent in early years because a lot of it will be taken up with planning and design of, for example, desulphurisers. One might consider initiating such a programme in parallel with research so that if the more morbid conclusions of some parts of the scientific community come out to be true then we will not have wasted any time and it will not be a great cost to start that programme going. It might be worthwhile looking for a bit more detail on exactly how the timing and the scheduling of an abatement programme might take place, because then it might not be necessary, in fact, I do not think it is necessary to take a big expensive decision now. Maybe you can start off with a fairly cheap lead in to your abatement programme. In terms of conservation, conservation is used, the term is used in a number of different ways. Sometimes it is

[Chairman *Contd.*]

used just in terms of reducing fossil fuel energy consumption. I like to use it in terms of reducing energy demand at the point of use and this means insulation of buildings, insulation of refrigerators, more efficient light bulbs, lower drag coefficiency for motor vehicles, etc., etc. There is an abundant range of conservation technologies which can be applied to almost any kind of energy use which one cares to consider and in terms of pollution one way of looking at the energy system is you are trying to fill a sieve by pouring water into it. The first thing to me, logically, is to try and block the holes of the sieve up before trying to find more water. I think this is what conservation does. When one does micro-economic analysis of conservation, one finds out it is cost effective compared to any form of energy supply. When one further considers the externalities, such as pollution, it reduces the pollution of the energy system so, for example, insulating refrigerators reduces the electricity demand and that will reduce acid pollution by reduction in pollution which is engendered by generation upstream in the energy system.

141. Can we pause for a moment. I would like to see, in practical terms, the effect of what you are saying is concerning the specific insulation of refrigerators. I do not know enough about them to know the extent to which they are insulated at the moment, how much more they could do with and what effect that might have once it was done; have you quantified all this?

(Dr *Barrett.*) Yes, last year for the Sizewell Inquiry we did a study of the potential for electricity conservation. This is a very restricted study. We looked at conservation of electricity in domestic appliances, in industrial and commercial lighting and industrial motor drive only those three things. We looked at electricity conservation measures which had a pay back time of less than four years. We looked at measures where the cost of saving a kilowatt per hour was a very small proportion of the cost of buying a kilowatt an hour of electricity. We attempted to see how you would support such a programme, the turnover of stock, to see how quickly conservation would affect electricity demand in the future. We came up with, I think, a very conservative view of electricity conservation because we omitted many sectors of demand such as electric space heating, for example, and came up with an electricity conservation programme which could be applied to the Scenario C which the CEGB have defined at the Sizewell Inquiry.

142. Can you tell me why refrigerators are not insulated to the optimimum possible at the moment because I would have thought if manufacturers did that they could claim that they were selling a very efficient cold-retention, heat-repellant machine with low running costs for the housewife. Why are they not doing it to the optimum?

(Dr *Barrett.*) There is the argument that market forces should lead to the optimal design of refrigerator. However, one of the things in the free market theory is information, and if you go into an elctricity salesroom and say, "I want to buy a refrigerator," and you have them at £100, £120, £150, you know the capital cost but then you ask them how much the running costs for each of them are and you will not get an answer, so that in fact the consumer, when it comes to purchasing end-use equipment like this—and this is not uncommon—cannot find out what the running costs of the device are as well as the capital costs. If you work it out, the amount you spend on putting electricity through the refrigerator is about the same as the cost of buying the refrigerator in the first place, and so I think that is a large part of the reason; the consumer has no way of telling a conserving refrigerator from an ordinary refrigerator.

143. What you are saying is manufacturers are skimping on the insulation in order to reduce the price of the product on the market and the consumer has to pay the extra through running costs?

(Dr *Barrett.*) Yes. Obviously if you do not know about the running costs all the consumer is going to look at is the capital cost as well as things like the knobs and buttons and the decor of the refrigerator.

Mr Chapman

144. You are suggesting there should be a British standard which says that refrigerators should have a certain insulation factor?

(Dr *Barrett.*) There are a number of things to do. First of all, there should be labelling so that you should be able to go into a shop and, if you are interested in energy conservation or concerned about running costs, you should be able to decide between various models. That is one thing. I personally feel as we have two standards, for example, on gas boiler efficiency or a num-

[Mr Chapman *Contd.*]

ber of energy-efficient, thermal-efficient, buildings, I do not see why we should not have for refrigerators. After all, when one looks at the electricity consumption of refrigerators, or freezers, it is about equivalent to two or three Sizewell Bs operating. That is the magnitude of it when they are all aggregated together. It is an enormous demand.

Mr Miscampbell

145. Could I come back to the Chairman's point. You have told us what you have looked at and may I say I am absolutely 100 per cent with you. I think they ought to have to show what the consumption is, just as people ask about motor cars, but the cost of petrol is so direct people are aware of it. The cost of electricity is so indirect they do not realise what is happening until they get the quarterly bill. I accept all that. What I do find difficult to quantify is this: assume we did the most we could, what difference is it going to make in our electricity consumption bearing in mind that only 50 per cent. of the acid that goes into the sky in any case comes from man-made pollutants and the rest is there anyway and only a small proportion actually does damage? What proportionate change in the damage, if we are doing damage and we may well be, would be made by your proposal? I am not saying this should not be taken in any event but whatever helps us on our particular problem as a practical statement I would be interested in.

*(*Dr *Barrett.)* There is a great problem with the timescale of this EEC directive. Ten years is a very short time in the lifetime of most technologies and for that reason alone the only two methods for abatement which I see as having a significant effect in ten years are conservation and scrubbing. If one extends that to 15 or 20 years it is a different matter. So, yes, I think what one should say is, look at all the options for abatement and do not rely on a particular option to do the whole job for you. What you should do is find the best mix of these options. There is a basic problem of what electricity demand will be anyway and one must remember that projections, for example, of the CEGB emissions made by the CEGB have a particular scenario in mind which may not come to pass, particularly since their scenarios were generated in 1982 and the recession has continued since then. So, my view is, yes, one should go for conservation but obviously in a ten-year period, given the inertia of electricity demand, that will not do the job of itself but one should do it nonetheless. Then, as far as I can see, the only other thing, with respect to the CEGB, would be to go for scrubbing. The programme which we have investigated only saves about 5 per cent. of electricity as compared with scenario C, which is now perhaps the maximum credible scenario for demand. My own view is that if the appropriate amounts of effort were put into electricity conservation in other sectors, such as electric space heating in houses, which is also a great cause of fuel poverty, then the savings might be 10 per cent. in ten years but it is limited. Everything is limited in ten years, even putting in scrubbing in a ten-year period. It is hard to achieve the target.

Mr Miscampbell: May I say I am very sorry I was late but may I ask a question I have asked others. Here we are facing this problem. We all assume—at least a number of people assume—that there is an acid rain problem which is being largely created by the burning of solid fuels, coals and also oil, but can you give me any explanation as to why, at the time when before the war we burnt 200 m tonnes of it we did not appear to have this problem, we are now faced with this at the time when we are burning 100 m tonnes and are saying this is what is causing it? May it not be that there are other complicated reasons for what has happened—afforestation, what we are putting on the land—dozens of reasons?

Chairman: We have touched on this in some of the earlier questions.

Mr Miscampbell

146. If you have, let us leave it.

*(*Mr *Rose.)* I think sulphur dioxide emissions peaked in about 1970. The other point I would like to come back to, if I may, is that you did mention 50 per cent. of the sulphur dioxide in the atmosphere was man-made. According to the Warren Spring study, the figure is something more like 90 per cent.

147. Others have given us different figures, I accept that.

*(*Dr *Holman.)* I think all over the world, on the global perception, 50 per cent, is the recognised figure but in terms of Europe 90 per cent. is the accepted level as being from man-made sources.

*(*Dr *Barrett.)* From the historical point of view I think it is a difficult question to

[Mr Miscampbell *Contd.*]

answer but there are other factors. For example, land drainage patterns will have changed the effect of acid pollution in rain on water, lakes and rivers, in that one does not have the buffering in water meadows and so on. To take sulphur dioxide out one has to look at the change in geographical patterns of use, and the last part of sulphur dioxide production will have occurred at lower levels in urban areas. We now have the situation where, as far as I understand it, in every conurbation in the United Kingdom there are significant polluters. Either you have to burn clean fuel for domestic use, for example, or it is emitted at a higher level. Therefore, although the total sulphur dioxide output from the United Kingdom may have diminished its effect on agricultural products and other things may not have done, so there are many factors.

(Mr *Rose.*) There is evidence in the Warren Spring study again, I think at Bracknell, that acidity in rural areas has increased and in nearby towns the sulphur dioxide levels have decreased because sulphur pollution is being spread further afield. Certainly lichens as indicators of sulphur dioxide pollution definitely show that in this country at least since the beginning of the century the clean places, the ones that were almost completely clean, are now slightly dirty and very dirty areas have cleaned up a bit.

Mr Roberts

148. If you were not working to the ten year time scale you suggested there were more effective things that could be done over a longer period rather than scrubbing or conservation, what would those be?

(Dr *Barrett.*) I do not think there is anything more effective than conservation. It seems to me in this respect anyway a panacea, but in the longer term use of renewable energy technologies could make a larger contribution. If there were a renewable energy programme in this country of a reasonable size then at the end of the ten year period, one might have technologies which could be proven in an economic sense and then, maybe start to implement them in the generation of electricity. That is not the case at the moment. There are also conventional things, fossil fuel technology such as fluidized combustion which many people think might, by the early 1990s, be a proven technology then and then, of course, that is useful both in terms of increasing energy efficiency and in terms of suppressing acid pollution. They are the main things in my view: conservation at the point of end use and on the longer time scale renewables and new technology.

149. You are saying if we want to set about doing something, the only two alternatives are the only two options which you take together, scrubbing and conservation?

(Dr *Barrett.*) Yes. What I tried to do, is I have looked at several methods of conservative efficient use of fossil fuels, for example in combined heat and power plants.

150. Does the combined heat and power plant not give up acid emissions?

(Dr *Barrett.*) It does but the amount of useful energy one derives per ton of coal consumption is roughly twice.

151. Because you use the waste heat?

(Dr. *Barrett.*) And that is also important; also combined heat and power will double the use, for example, in heating so it is a double effect. It seems that is going to be an important option given the very important thing that we use a lot of natural gas at the moment with low sulphur content. Although our sulphur dioxide emissions may be diminishing what is going to happen when North Sea gas declines? The other options low sulphur fuel, low sulphur coal and oil imports are options to be considered. My own view is that if there is a legislative control of pollution that low sulphur fuels are going to be much more expensive so that the economic gain of using low sulphur fuel is unlikely to be much use on a large scale. Then one comes down to options of renewable and nuclear power and finally desulphurisation, taking the sulphur out of fuel before, during or after combustion. In my view that is going from the best to the worst.

152. What do you think about the option of more nuclear energy?

(Dr *Barrett.*) In terms of reducing acid pollution it is a possibility. However, I think one must consider the economics of it, historically have not worked out very well and there is obviously a lot of contention about the proposed PWR. But, further, I think there is a great difficulty if public perception of radioactive pollution changes in the same way as that for acid rain, then I think one could be in for the same difficulty and not being unbiased, as perhaps not many in this room are, I see a lot of anxiety

[Mr Roberts *Contd.*]
about radioactive pollution at Sellafield and some of the Magnox stations, I think it is a bubble which could burst.

Mr Smith

153. It is a follow up to that last question which is to ask you how you would react to the statement which the CEGB made to us that in their view it was currently difficult without any desulphurisation machinery or denitrification process in fossil fuel burning plants and it may be more economic to go nuclear than for fossil fuel power stations. You seem to suggest that was not your view when you talked about the economics. Would you like to expand on that and would you perhaps like to give your view? I am surprised that you are so cagey about desulphurisation and denitrification processes which admittedly are expensive but in Germany, for example, they are the mechanism which the German Government seem to have decided as being the vehicle for reducing pollution. Apart from expense, is there any other reason why you were so reluctant about that?

(Dr *Barrett.*) Yes, as I explained it first of all, I go for a preventive approach in that the trouble with desulphurisation, washing of coal or desulphurisation during combustion or the scrubbing of flue gases after combustion is that the sulphur does not disappear, it is merely transferred to another compound, a range of chemical compounds and what does one do with the waste products from these desulphurising processes? If one takes coal washing, for example, one loses some of the energy content of the coal which is obviously an economic loss in itself and there is the problem of if one has great piles of high sulphur coal waste lying on the ground that some of the sulphur products can leach into the ground. If one takes desulphurisation during or after combustion then, again, one has chemical compounds such as the gypsum formed, for example, and so one must then consider is there a way of selling the stuff to markets so we do not have to dump it on the ground because the quantities involved are considerable. For example for every ton of sulphur there will be, I think, about five tons of gypsum—considerable quantities. My own view is you have to think carefully before taking the stuff out and dumping it on the ground by a power station as a wet slurry which could cause environmental problems. Fortunately the study so far, looking at product markets for gypsum and sulphuric acid, which can be made from the two commonly discussed types of components, the markets would seem to be able to absorb something like 60 per cent of the current sulphur dioxide emissions but this is something where the potential seems to be there.

Chairman

154. The Germans gave us evidence they were going to use a lot of this for the construction industry, making roads, but that would not commend itself to the Friends of the Earth—making roads. But to finish what Mr Smith was saying, I think the Germans were telling us they hope to reduce their sulphur dioxide emission by 95 per cent by 1988. I take it you do not suggest we emulate that example?

(Dr *Holman.*) We are supporting the draft EEC directive asking for a 60 per cent reduction from 1980 to 1995. On that time scale the only option is by flue gas desulphurisation. There is no other option. On the nuclear option, we could not build enough nuclear power stations in that time to reduce our emissions by 60 per cent., so the timescale is quite an important factor to take into consideration. We feel that on the balance of the evidence we need to act now, as we have already said, and, therefore, we are backing that draft EEC directive and asking for desulphurisation over the next ten years.

Mr Alexander

155. Whilst accepting it has not reduced the emissions to the extent you say, are you able to say by what percentage this would reduce acid rain damage in Britain and in Europe?

(Dr *Holman.*) No, this is a problem in that no-one can actually say if you reduce sulphur emissions by X per cent. what effect that will have on the environment, but I think we will see a reduction in sulphur dioxide levels in the atmosphere and we know what sulphur dioxide levels affect building materials and we know that it might have a possible effect on trees and on crops in combination with sulphur dioxide. We know that 70 per cent. of the acid rain comes from sulphur dioxide emissions and, therefore, it should help to reduce the acidity of the lakes and rivers in Scandinavia and also those in Scotland and Wales which are affected and should also stop any further acidification of fresh waters, which are on the balance at the moment and are just about the tick over to 100 per cent. acidification, so I think we will stop seeing further damage, what it will actually do in terms of the acidified fresh waters which are acidified at the present time. It is likely to be a very slow process to return these lakes to their natural state and, therefore, I do not think we can say we will see any such recovery in the thousands of lakes damaged in Scandinavia, but I would hope over the timescale of several decades their situation will improve, but we should stop further damage.

(Mr *Rose.*) The reason we cannot put a figure on it, a guesstimate, is that the atmospheric models are not good enough or detailed enough with respect to Britain and Western Europe to do that, as opposed, for example, to the problem of global carbon dioxide all across the United States and the figures that they come up with for ozone and sulphur dioxide there.

156. I was interested in Dr Homan's last answer, that by doing this we should stop further damage. It is your considered view that if this directive is put into effect, one decade, two decades, maybe four decades away, further acid rain damage will be stopped?

(Dr *Holman.*) No, that is not what I said. Those guesstimates of the timescales were in relation to the acidified fresh waters, fresh waters that are already acidified today, in terms of the reversibility of this process, that I think it will take a long time for us actually to see those acidfied lakes and rivers return to their natural state. I do think if we stop sulphur emissions we will stop further acidification of lakes which are not acidified at the present time.

Mr Alexander: That is why I asked that question, to make that clear.

Mr Smith

157. Can I come back on the question which you did not answer, which was the one about the economics of nuclear power as opposed to fossil fuel power production?

(Dr *Barrett.*) I have not studied this closely. All I can say is that in terms of the historical record of investment in nuclear powers in the Magnoxes and the AGRs, it has not been a success as compared with coal generation. This is what we know has happened. In terms of what might happen in future, whether we can start building power stations to programme, whether they will reach the load factors and the technical performance which are projected for them, whether the costs will work out as they say, I think these are greatly uncertain for nuclear power and the disbenefits are quite large. My own view from my peripheral involvement with the Sizewell Inquiry is that the case for nuclear power, the PWR in particular, does not look good. You certainly could not build one within the next ten years. It is not a matter of capacity shortfall but rather of presumed economic savings due to reduced fossil fuel burn and so definitely the case for Sizewell, as far as I can see, rests on all these future possibilities. When one takes that plus the historical record of nuclear power within this country and within America, and the PWRs in particular, I remain to be convinced. I do not see the necessity for our taking the decision at the moment. Quite frankly, you do not need another power station, nor do you want one.

Chairman

158. Just one final matter: as you make no reference at all to it in your paper, I assume you cannot help us as to whether or not the motor vehicle makes any contribution or otherwise to air pollution?

(Dr *Holman.*) I think it is very well proven that the emissions of hydrocarbons and oxides of nitrogen from motor vehicles do contribute to the elevated levels of ozone which have been seen throughout Western Europe and, therefore, if it is decided that ozone is one of the pollutants we should have some sort of abatement strategy for, you are talking about putting some sort of catalytic converter on the exhausts of motor vehicles.

Mr Roberts

159. You have to go lead-free before you can do that?

(Dr *Holman.*) Yes. We hope within Europe the path has been laid to enable us to do that.

Chairman: If there are no further questions, Mr Rose, Dr Holman and Dr Barrett, may we thank you very much for coming to answer our questions this afternoon.

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MONDAY 11 JUNE 1984

Members present:

Sir Hugh Rossi, in the Chair

Mr Richard Alexander
Mr David Alton
Mr Sydney Chapman
Mr Reg Freeson
Mr Robert B Jones
Mr John Mark Taylor

Memorandum submitted from the Department of the Environment

ENQUIRY ON ACID RAIN

I INTRODUCTION
II EMISSIONS OF SULPHUR DIOXIDE (SO_2) AND OXIDES OF NITROGEN (NO_x) IN THE UK AND OTHER EUROPEAN COUNTRIES
III DEPOSITION OF POLLUTANTS IN THE UK AND OTHER EUROPEAN COUNTRIES
IV ACIDIFICATION OF THE ENVIRONMENT AND THE ROLE OF ACID DEPOSITION
V RESEARCH ON ACID DEPOSITION AND ITS EFFECTS
VI EMISSION CONTROL OPTIONS
VII UK RESEARCH ON CONTROL TECHNOLOGIES
VIII INTERNATIONAL ASPECTS
IX UK CONTROL LEGISLATION

ANNEX Atmospheric transformation processes

ADDITIONAL PAPER PREPARED BY THE BUILDING RESEARCH ESTABLISHMENT (DOE) (concerning the effects of acid precipitation on buildings)

I INTRODUCTION

1. "Acid Rain" is a misleadingly simple term for the complex problem of acid deposition and its effects on the environment. Although most of the deposited acidity arises as a result of the combustion of fossil fuels, natural processes also provide a significant background. Deposition takes place not only in wet forms, through rain, mist and snow, but also in dry forms through gases and particles. Deposition is generally agreed to affect water bodies, vegetation, and buildings; but understanding of the processes involved, and of possible remedies, is still developing.

2. Effects on lakes and forests, in particular, are matters of considerable political concern in many countries and internationally; and pressures for remedial action are mounting even while scientific debate about the most effective remedies is still some way from consensus.

3. This paper gives an account of the Department of the Environment's present understanding of the scientific issues, the options available for control of emissions, relevant current research, the legislative framework, and the background of international discussion. A detailed treatment of atmospheric transformation processes is annexed.

4. The Department emphasises that this is a rapidly evolving area of knowledge and of international debate, with no overall scientific consensus. Various of the statements in this paper will undoubtedly be qualified by subsequent discussions, and disputed by other experts. All that we can do at present is to strike the best balance that we can.

The cost of printing and publishing these Minutes of Evidence is estimated by Her Majesty's Stationery Office at £4,200.

II EMISSIONS OF SULPHUR DIOXIDE (SO_2) AND OXIDES OF NITROGEN (NO_x) IN THE UK AND OTHER EUROPEAN COUNTRIES

1. In the UK, the published emission data are derived from fuel use data by the application of percentage factors. This approach produces figures of broad accuracy. It is not known how emission data from other countries are prepared, but differences in method and in the reliability of the underlying information must make comparisons somewhat uncertain.

Sulphur dioxide

2. UK SO_2 emissions peaked at 6m tonnes in 1970 and since then there has been a steady reduction, amounting to 34 per cent up to 1982 (Table 1 to this section). This reduction has occurred mainly in the industrial sector. As there has been little change in emissions from power stations the latter have assumed a greater relative importance—their contribution to total emissions rising from 48 per cent in 1971 to 66 per cent in 1982.

3. Over the same period total energy consumption has changed little, but the use of sulphur-free North Sea gas has increased at the expense of sulphur-bearing fuel oil. It is this change that has been the main cause of the reduction in sulphur emissions (Table 2 to this section). Emissions of SO_2 from coal combustion have varied over the period with no consistent trend, but with a significant reduction in 1982 as compared with 1971. In terms of relative importance, the contribution from coal to total emissions has increased from about 53 per cent in 1971 to 70 per cent in 1982.

Nitrogen Oxides

4. Table 3 to this section shows estimated emissions of NO_x (expressed as nitrogen dioxide equivalent) derived from the UK fuel consumption data and from emission factors appropriate to the process and fuel concerned. Emission factor data are limited and the statistics presented in the Table should be regarded only as best estimates. Assuming constant emission factors the data can be related directly to trends in fuel use. This assumption may not apply to data for road vehicle emissions due to changes in technology.

Emissions in other European Countries

Sulphur Dioxide

5. The information available on emissions of SO_2, and trends is summarised in Table 4 to this section. The many gaps in the Table reflect the absence of published figures, and it is not known whether all countries produce data which is on a comparable basis to that of the UK. However, crude estimates based on known and estimated total fuel use data suggest that emissions in Europe (excluding USSR) have doubled since 1950 at which time, the UK contributed about 25 per cent of the total of emissions. Current UK emissions are 12 per cent below 1950 levels and the UK contribution to total European emissions in 1982 had fallen to about 11 per cent.

Nitrogen Oxides

6. Emission data for NO_x in Europe is even more sparse than for SO_2. Available data is summarised in Table 5 to this section but emission factors are uncertain and information on the methodology used in other countries is virtually non-existent. The use of this data to indicate trends is probably subject to the least uncertainty. In this regard, the UK shows little change in emissions over the past 10 years, whilst there may have been marginal increases in France, FRG and in other countries where a run of data exists.

Estimates of UK and NO_x emissions to 2010

7. Estimates of UK emissions of SO_2 and NO_x have been made based on the Department of Energy's projections of long-term energy demand to 2010. These projections are by their very nature subject to great uncertainty. They include alternative assumptions about the level of world economic activity, international fuel prices and the growth and structure

Sulphur dioxide: emissions from fuel consumption

Table 1 *to section II*
m tonnes

I *By type of consumer*

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982[a]
Domestic	0.52	0.46	0.37	0.36	0.35	0.30	0.28	0.29	0.26	0.26	0.22	0.21	0.20
Commercial/public service[2]	0.39	0.34	0.31	0.29	0.26	0.24	0.24	0.24	0.23	0.24	0.20	0.18	0.17
Power stations	2.77	2.80	2.87	3.02	2.78	2.82	2.69	2.74	2.81	3.10	2.87	2.71	2.65
Refineries	0.24	0.25	0.26	0.29	0.30	0.26	0.28	0.27	0.29	0.29	0.28	0.22R	0.21
Other industry[3]	2.12	1.94	1.75R	1.77R	1.59	1.44R	1.42R	1.37R	1.36R	1.38R	1.05R	0.84R	0.76
Rail transport	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01
Road transport	0.04	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.04	0.05	0.05
All consumers	6.12	5.86	5.64R	5.80R	5.35R	5.13R	4.98R	4.98R	5.02R	5.34R	4.67	4.28R	4.04

Table 2 *to section II*
m tonnes

II *By type of fuel*

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982[a]
Coal	3.34	3.04	2.65	2.89	2.56	2.68	2.74	2.79	2.77	3.10	3.02	2.91	2.75
Solid smokeless fuel	0.25	0.20	0.18	0.17	0.16	0.15	0.13	0.13	0.13	0.13	0.10	0.10	0.10
Petroleum:													
Motor spirit	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.03	0.02
Derv	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
Gas oil	0.16	0.16	0.20	0.20	0.17	0.17	0.16	0.14	0.14	0.14	0.09	0.07	0.07
Fuel oil	2.07	2.16	2.29R	2.20	2.10R	1.82R	1.61R	1.58R	1.64R	1.62R	1.13	0.86R	0.86
Refinery fuel	0.24	0.25	0.26	0.29	0.30	0.26	0.28	0.27	0.29	0.29	0.28	0.22R	0.21
All fuels	6.12	5.86	5.64R	5.80R	5.35R	5.13R	4.98R	4.98R	5.02R	5.34R	4.67	4.23R	4.04

Nitrogen oxides: estimated emissions by source

Table 3 *to section II*
thousand tonnes

	1970	1971	1972R	1973R	1974R	1975R	1976R	1977R	1978R	1979R	1980R	1981R	1982
Domestic	40	49	51	53	53	51	50	52	52	56	52	52	51
Commercial and industrial	766	690	470	486	449	408	419	415	405	417	338	318	309
Power stations	778	755	731	808	722	760	770	793	806	876	851	818	769
Incineration and agricultural burning	6	8	8	8	8	10	12	12	12	12	12	12	12
Road vehicles:													
petrol engined	385	247	262	279	272	266	279	286	303	308	316	309	318
diesel engined		156	158	170	166	162	168	171	176	182	176	167	72
Railways	58	54	48	50	47	44	41	42	42	41	40	39	35
All emissions	2,037	1,958	1,728	1,854	1,716	1,700	1,739	1,771	1,796	1,893	1,785	1,714	1,666

of the UK economy. The emission figures based on power station, industry and other fuel use calculated from these assumptions can therefore only be interpreted as giving a broad indication of the likely emission trend.

8. The energy projections cover a reasonably wide range of variations in the main assumptions and it is difficult to select the most appropriate scenario on which to base emission estimates. However, from the eight scenarios submitted to the Sizewell Inquiry, one which gives the highest level of projected emissions has been deliberately selected ie that based on a GDP growth rate of two and a half per cent pa and a relatively low oil price. Assuming no changes in present emission controls, UK emissions shown below have been calculated from this scenario:

Emissions	*1980*	*1990*	*2000*	*2010*
SO_2 m tonnes	4.7	4.5	4.8	4.0
NO_x m tonnes	1.8	2.1	2.2	2.0

III DEPOSITION OF POLLUTANTS IN THE UK AND OTHER EUROPEAN COUNTRIES

Deposition in the UK

1. Data on acid precipitation in the UK have recently been published in a report by the Warren Spring Laboratory on behalf of the Department; a copy of this report has been deposited in the Library of the House of Commons. Annual deposits in the UK (based on 1978/79 emissions) total some 1 million tonnes of sulphur, but are unevenly distributed. The maps and tabulations in the Warren Spring report indicate that the western

Table 4 to section II

EUROPEAN SULPHUR DIOXIDE EMISSIONS m tonnes

	1950	1960	1971	1972	1973	1974	1975
Albania	—	—	—	—	—	—	—
Austria	—	—	—	—	0.700	—	—
Belgium	—	—	—	—	0.998	0.760	—
Bulgaria	—	—	—	—	1.000	—	—
Czechoslovakia	—	—	—	—	3.000	—	2.800
Denmark	—	—	—	—	0.623	—	—
Finland	—	—	—	—	0.549	—	0.535
France	(1.18)	(1.92)	2.966	3.493	3.703	3.711	3.146
Germany E	—	—	—	—	4.000	—	—
Germany W	(2.72)	3.450	3.800	—	3.928	3.750	3.550
Greece	—	—	—	—	—	—	—
Hungary	—	—	—	—	1.500	—	1.318
Ireland	—	—	—	—	0.330	—	—
Italy	—	—	—	3.200	3.169	—	—
Luxembourg	—	—	—	—	0.046	0.048	—
Netherlands	(0.325)	0.694	0.650	0.580	0.782	0.530	0.419
Norway	(0.07)	—	0.169	—	0.181	—	—
Poland	—	—	—	—	3.000	—	2.080
Portugal	—	—	—	—	—	—	0.178
Romania	—	—	—	—	—	—	—
Spain	—	—	—	—	1.297	1.451	3.004
Sweden	0.500	—	—	—	0.829	—	0.690
Switzerland	—	—	—	—	0.151	—	0.116
Turkey	—	—	—	—	—	—	—
USSR	—	—	—	—	23.500	—	24.000
UK	4.61	5.68	5.86	5.64	5.80	5.35	5.13
Yugoslavia	—	—	—	—	—	—	—

Source: Figures for 1973 and 1978 are taken from an ECE survey of member states whilst those for 1980 are taken from an OECD survey. Otherwise, the figures have been derived from official publications except for those in parenthesis which have been estimated from other sources.

Table 4 *to section II continued*

EUROPEAN SULPHUR DIOXIDE EMISSIONS m tonnes

	1976	1977	1978	1979	1980	1981	1982
Albania	—	—	0.100	—	—	—	—
Austria	—	—	0.430	—	0.444	—	—
Belgium	—	—	0.808	—	0.809	—	—
Bulgaria	—	—	1.000	—	1.000	—	—
Czechoslovakia	—	—	2.950	—	3.100	—	—
Denmark	—	0.455	0.455	—	0.455	—	—
Finland	0.570	0.520	0.560	0.560	0.570	—	—
France	3.605	3.208	3.385	3.529	3.262	2.504	2.378
Germany E	—	—	4.000	—	—	—	—
Germany W	—	—	3.550	—	3.580	—	—
Greece	—	0.704	0.700	—	0.700	—	—
Hungary	—	—	1.640	—	1.633	—	—
Ireland	—	—	0.250	—	—	—	—
Italy	—	—	4.400	—	5.160	—	—
Luxembourg	—	—	0.030	—	—	—	—
Netherlands	0.463	0.480	0.490	0.480	0.440	0.485	—
Norway	0.207	—	0.150	0.147	0.143	—	—
Poland	2.308	—	2.500	—	2.755	—	—
Portugal	0.217	0.181	0.187	0.237	0.264	—	—
Romania	—	—	0.200	—	0.200	—	—
Spain	3.344	3.296	3.570	3.756	—	—	—
Sweden	—	—	0.530	—	0.510	—	—
Switzerland	—	—	0.124	—	0.119	—	—
Turkey	—	—	1.000	—	1.000	—	—
USSR	—	—	24.500	—	—	—	—
UK	4.98	4.98	5.02	5.34	4.67	4.23	4.04
Yugoslavia	—	—	2.950	—	3.000	—	—

areas of the UK receive the largest inputs of acidity from wet deposition. The amount of such precipitated acidity in the western regions of the UK is of the same order as in the sensitive regions of Scandinavia and North America. The report also gives data regarding dry deposition of SO_2 and NO_x in the UK.

2. There is evidence from OECD studies that some of the sulphur deposited in wet deposition on Europe's western sea board may have been transported across the Atlantic. Indeed some 25 per cent of deposition in Norway is thought to be of this kind. It is reasonable to suppose that much of this Atlantic sulphur originates from emissions in the USA and Canada.

3. The Warren Spring report reveals the fact that a large percentage of total annual wet deposition occurs on a relatively few wet days each year (such events are known as episodes). Such study as there has been of the origin of such episodes has shown that they are usually associated with air masses which have traversed major emission sources either in the UK or in the rest of Europe. There are also seasonal variations in the concentrations and deposition of pollutant species in rain. This variability in time is important when effects are considered. The occurrence and origin of these episodes and seasonal variations may well also have significant implications for possible control strategies. If, for example, an episode could be predicted, its magnitude might be reduced if the power stations involved switched for a period to low-sulphur fuels.

Deposition in Europe

4. Much less is known about deposition in Europe as a whole than in the UK. Information is available on depositions, expressed as sulphur, from the Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air

Table 5 to section II

EUROPEAN NITROGEN OXIDE EMISSIONS

	1965	1966	1970	1971	1974	1975	1976	1977	1978	1979	1980	1981	1982
Austria	—	—	—	—	—	—	—	—	0.547	—	—	—	—
Belgium	—	—	—	—	—	—	—	—	—	—	0.150	—	—
Denmark	—	—	—	—	—	—	—	—	—	—	0.241	—	—
Finland	—	—	—	—	—	—	—	—	0.178	—	—	—	—
France	—	—	—	1.170	1.312	1.256	1.375	1.376	1.430	1.481	1.455	1.369	1.377
Germany W	—	2.050	2.450	—	2.700	—	—	—	3.000	—	—	—	—
Greece	—	—	—	—	—	—	—	—	0.196	—	—	—	—
Italy	—	—	—	—	—	—	—	—	1.270	—	—	—	—
Netherland	—	—	—	—	—	—	—	—	0.505	—	0.506	—	—
Norway	—	—	—	—	—	—	—	—	—	—	0.073	—	—
Portugal	—	—	0.072	—	—	0.104	0.153	0.167	0.196	0.221	0.247	—	—
Spain	—	—	—	—	—	0.624	0.700	0.726	0.772	0.811	—	—	—
Sweden	—	—	—	—	—	0.310	—	—	0.320	—	0.320	—	—
Switzerland	—	—	—	—	—	—	—	—	0.161	—	—	—	—
Turkey	—	—	—	—	—	—	—	—	0.380	—	—	—	—
UK	—	—	—	—	1.716	1.700	1.739	1.771	1.796	1.893	1.785	1.714	1.666

Source: Except for the UK and France which publish national data, the information is derived from OECD sources.

Table to section III
m tonnes

Average annual sulphur(1) budget for Europe in Period October 1978 to September 1980

	Emissions			Deposits within individual countries							
	Total originating from individual countries	Deposited in other countries		From own emissions		From other countries		Undecided background deposition		Total	
	m tonnes	m tonnes	%	m tonnes	%	m tonnes	%	m tonnes	%	m tonnes	kg/ha
Albania	0.05	0.02	40	0.01	15	0.05	67	0.01	18	0.08	28
Austria	0.21	0.12	56	0.06	15	0.31	76	0.04	9	0.41	49
Belgium	0.38	0.21	55	0.08	42	0.10	53	0.01	6	0.19	63
Bulgaria	0.50	0.25	50	0.18	44	0.20	47	0.03	8	0.42	37
Czechoslovakia	1.50	0.82	55	0.58	37	0.87	56	0.11	7	1.56	122
Denmark	0.23	0.10	42	0.05	36	0.07	54	0.01	10	0.13	30
Finland	0.27	0.08	30	0.09	26	0.19	55	0.07	19	0.35	10
France	1.80	0.68	38	0.75	52	0.50	34	0.20	14	1.45	27
Germany E	2.00	1.30	65	0.60	64	0.31	33	0.03	3	0.93	86
Germany W	1.81	1.08	60	0.67	48	0.62	45	0.10	7	1.39	56
Greece	0.35	0.08	24	0.11	37	0.15	51	0.04	12	0.30	23
Hungary	0.75	0.60	80	0.23	42	0.30	54	0.02	4	0.56	60
Ireland	0.09	0.02	28	0.02	28	0.03	32	0.03	40	0.08	11
Italy	2.20	0.69	31	0.95	70	0.30	22	0.11	8	1.36	45
Luxembourg	0.02	0.02	85	<0.01	27	0.01	73	0	0	0.01	51
Netherlands	0.24	0.14	60	0.05	23	0.15	70	0.01	6	0.21	51
Norway	0.07	0.02	31	0.02	8	0.19	63	0.09	29	0.31	9
Poland	1.50	0.86	58	0.68	42	0.82	52	0.09	6	1.60	51
Portugal	0.08	0.02	21	0.02	27	0.03	33	0.03	40	0.09	11
Rumania	0.10	0.04	42	0.03	5	0.54	84	0.07	11	0.65	27
Spain	1.00	0.19	19	0.44	63	0.13	18	0.13	19	0.70	14
Sweden	0.27	0.09	34	0.10	18	0.33	58	0.14	24	0.57	13
Switzerland	0.06	0.05	81	0.02	10	0.13	78	0.02	12	0.17	41
Turkey	0.48	0.08	16	0.21	42	0.19	39	0.09	19	0.50	11
USSR	8.10	0.28	4	4.33	52	2.68	32	1.27	15	8.28	25
UK	2.56	0.71	28	0.81	80	0.12	12	0.09	8	1.02	42
Yugoslavia	1.47	0.90	61	0.67	51	0.54	41	0.10	8	1.31	51

Note: (1) The figures refer to sulphur only since sulphur dioxide is not deposited. Emission figures may be converted from sulphur to sulphur dioxide by multiplying by 2.

(2) Totals may not correspond exactly because of rounding errors.

Pollutants in Europe (EMEP) which operates under the UN/ECE Convention on Long-Range Transboundary Air Pollution (LRTBAP). Depositions are calculated by the use of a mathematical model on the basis of data supplied by the individual countries. The latest data available are summarised in the Table to this section.

5. The UK is the largest emitter of SO_2 in Western Europe, but it is not as often stated, the largest contributor, in total, to deposition in other countries. 32 per cent of our emissions are deposited in the UK, 28 per cent in other countries and, because of our geographical position some 40 per cent is deposited in the sea. The FRG, the GDR, Poland, Czechoslovakia and Yugoslavia all contribute more, in total, to other countries' depositions than the UK and France and Italy contribute only marginally less. The quantities involved are shown in the Table to this section.

6. Deposits in the UK at 1.02 million tonnes of sulphur per year (using 1978 emission figures) are less than in the USSR, Poland, Czechoslovakia, France, Italy, Yugoslavia and the FRG. In terms of deposition per unit area the UK lies in the middle range with an annual deposition of 42 kilogrammes/hectare.

IV ACIDIFICATION OF THE ENVIRONMENT AND THE ROLE OF ACID DEPOSITION

1. The effects of acid deposition remain the subject of considerable scientific debate. Few doubt that such effects are real; but their magnitude, their cost and the relative roles of deposited acidity, direct toxicity of atmospheric pollutants, land-use changes and slow natural processes in soils and aquatic systems, all remain uncertain. A recent Royal Society discussion covered many of these questions.

2. A large volume of research on all aspects of the acid deposition problem has been, and continues to be, published. The sheer volume of such work, and its uneven quality, brings with it real problems of assessment and assimilation. The present section should be regarded as an attempt to evaluate the current balance of evidence, but in full recognition of the certainty of changing perspective as research proceeds (see section V).

3. The position is complicated by the fact that effects can be direct (eg when dry deposition affects trees or stonework) and indirect (eg when acidity influences fish through changes in the chemistry of their habitat or tree roots through changes in soil). In the following paragraphs we consider:

(a) direct effects on trees and other plants;
(b) effects on soils and the plants that grow on them;
(c) effects on freshwaters and the life they support;
(d) effects on materials;
(e) possible effects on human health.

Effects on Trees and Vegetation

4. It is well known that high concentrations of SO_2, and other pollutants such as ozone, cause damage to vegetation and there is extensive botanical literature on this subject. But it is only a relatively recent development to ascribe serious vegetation damage to current levels of SO_2 and NO_x emissions. In 1972, the Swedish Government submitted a case study to the UN Stockholm Conference arguing that there was a risk of forest damage from this cause. Subsequent research cast doubt on this assertion. But particularly strong claims have been made in the past three years as regards forest damage in the Federal Republic of Germany (FRG) and in other mid-European countries such as Switzerland and Austria. There is no doubt that die-back is occurring in spruce and fir trees in these countries. Initially this was observed at high altitudes in the Black Forest and in Eastern Bavaria but it has now spread to lower altitude forests and to other areas of the FRG and is said to affect 30 per cent of the forest stands. The damage is manifestly increasing in severity and geographical extent, even allowing for the fact that the amount of damage reported would increase because the attention of foresters has now been drawn to the problem.

5. Recently there have been reports of forest damage also in Sweden and in contrast to earlier statements, these are widely accepted by foresters. Other reports have come from North America although the evidence does not yet appear so convincing as that produced in the FRG. In the UK there is well-substantiated evidence of acute damage to conifer plantations in certain industrial areas (notably the Southern Pennines) where improvement has followed clean air policies in the past 20 years.

6. Acid deposition was first considered as a likely cause of the observed tree damage in the FRG. The mechanism some botanists regard as most plausible involves some damage to leaf tissues by the direct effect of SO_2 (or ozone) which renders them more liable to the leaching of magnesium and calcium by percolating acidified rainwater. The roots take up these substances in an attempt to compensate (with consequent acidification in the soil) and this can in turn cause the release of soluble aluminium from the soil minerals: this aluminium is highly toxic to root systems. There are signs that spruce exhibiting die-back in the FRG also exhibits magnesium deficiency in the needles, but it must be stressed that many botanists do not regard the mechanism outlined above as proven or universal, although it may well explain what happens in some areas.

7. A substantial body of evidence and opinion now seems to be pointing to the considerable importance of gaseous pollution particularly ozone. Concentrations of ozone measured in the Black Forest in areas where damage has been occurring are comparable to those in the United States, where ozone is known to cause forest injury. They also match concentrations known to have an effect in the laboratory. Mean ozone concentrations are consistently greater at higher altitude sites in the FRG and the United States which is suggestive since greater damage is observed at higher altitudes. The DOE has commissioned an expert consultant's report which concludes that these kinds of coincidence make it plausible to argue that ozone could be a causative factor in the observed forest damage. However, it must be emphasised that there is as yet little direct experimental evidence to resolve this question. There is also uncertainty about the possible significance of ozone pollution in the UK. Although peak levels of ozone in the recent hot summers have been similar in the UK to those in the remainder of Europe, annual mean concentrations in the UK have been lower than those elsewhere. In this regard it is important to confirm the recent reports of forest damage in the UK similar to that in the FRG.

8. The formation of ozone is a photochemical reaction involving nitrogen oxides and hydrocarbons—a fuller account of this topic prepared by the Department's consultants is annexed. As noted in the 10th Report of the Royal Commission on Environmental Pollution an equilibrium is set up between nitrogen oxides, oxygen and ozone in the presence of sunlight:—

$$NO_2+O_2 \leftrightharpoons NO+O_3.$$

This reaction moves to the right in sunlight and to the left in darkness. However, in the presence of sunlight many hydrocarbons react with oxygen to produce free radicals (highly reactive chemical species) which convert NO to NO_2—the net result being an increase in the amount of ozone. If ozone is the major cause of forest damage, then attention must be given not only to local NO_x concentrations but also to the presence of hydrocarbons either anthropogenic or natural, that is damage cannot be ascribed entirely or even mainly to acid precipitation.

9. There have been considerable studies of the direct effects of SO_2, NO_x and ozone, singly and in combination, on crop plants and species grown for amenity. Some reductions in yield of sensitive strains, for example of tobacco, are documented in the United States. In the area around Los Angeles, ozone and other oxidants produced in "photochemical smog" undoubtedly harm commercial growth of citrus and other crops over a wide area. The magnitude of any such effects in the environmental conditions that prevail in Europe is a matter of debate, which has tended to be overshadowed by the debate over forest damage.

Effects on and through the soil

10. Acidification of soils is a natural long-term process. Over much of Europe, the retreat of the glaciers at the end of the last Ice Age left soils that were high in minerals. Weathering and the continual percolation of naturally acid rain has released and removed these minerals. This natural trend in acidification is most prevalent in areas of high rainfall and of hard rock geology which provides soils of only low neutralising capacity. This trend would be expected to accelerate if the acidity of the rainfall increased.

11. In the UK the soils in the eastern regions have the highest capacity to neutralise acidity, and it is not surprising that effects of acid deposition there appear to be small. The western part of the UK not only receives the largest quantity of deposited acidity, but contains large areas of hard rock cover with relatively low neutralising capacity, so that acidification effects will be enhanced. These areas have naturally acid soils and vegetation types like sphagnum bogs, heather moors and grass and sedge assemblages adapted to such conditions. The water draining from such areas can also be expected to be naturally acid.

12. There are many processes within soils and their vegetation cover that can increase their acidity (and therefore that of run-off). The decomposition of plant material and humus releases nitrogen compounds which are converted to nitric acid (the breakdown of tree roots killed by aluminium is thus considered to release more acidity, liberating more aluminium and aggravating the situation described in para 6). Application of nitrogenous fertilisers to soils of limited neutralising capacity (for example as a prelude to afforestation) can have the same result. In addition organic acids are produced by the decay of leaf litter and plant residues and can also contribute both to soil acidity and the removal of neutralising capacity. Calcium and magnesium are particularly liable to removal from soil by acidification, and they are important plant nutrients. The bacterial oxidation of mineral and organic sulphides in the soil is yet another source of acidity.

13. Forests act as an effective trap for acidic emissions, and it is found that water falling through the leaf canopy (throughfall) or passing down the main stem (stemflow), especially of old coniferous trees, is likely to be more acid than the incoming precipitation. Tree growth itself leads to the removal of metallic cations (positively charged ions) from the soil which are replaced by hydrogen ions giving increased acidification. Indeed afforestation increases the rate of environmental acidification. Some plants, particularly sphagnum moss, are particularly effective at removing cations and releasing acidity into the local environment.

14. It is thus evident that there is a wide range of factors involved in the acidification of soil, and that the deposition of sulphuric and nitric acids resulting from human activities is only one component in a complex situation. The characteristics of soil and vegetation must be taken into account if any predictions of the effects of acid deposition are to be made. A rough assessment indicates that most agricultural soils in the UK are relatively rich in lime, or high in clay and silt, and as such have a considerable neutralising capacity.

Effects on Drainage Waters and Freshwater Systems

15. The arguments over the effects of acid deposition on freshwater systems commonly evade the fact that very little deposition—dry or wet—goes directly into the aquatic environment. Almost all of it passes through the vegetation and soil cover and is modified in the process. The prediction of the likely acid inputs to a lake or river system therefore demands knowledge of the soils and the drainage characteristics of the catchment.

16. Freshwater ecological systems are undoubtedly sensitive to acidification. The first changes attributed to the process were in salmon fisheries in Southern Scandinavia in the early years of the present century, and it was the disappearance of fish (notably trout) from many lakes in this region between 1940 and 1970 that was until recently the main focus of concern.

17. There seems little doubt that acidification reduces the hatching rate of fish eggs, the survival of fry, and the continuance of fish populations. Work in North America and Scandinavia has led to the definition of the conditions that appear critical for many species. Similarly, invertebrate animals and the plants that grow on river and lake beds or float in the surface waters show a sequence of disappearance along the gradient of increasing acidity. Such broad patterns are well documented and generally accepted. What is uncertain is the precise chain of cause and effect.

18. The concentration of acids and metals in rivers and lakes depends upon how incident precipitation moves through and interacts with the catchment area. As acidic rainfall passes over or through the soil cover it will dissolve different metals. If the neutralising capacity of the soil is high calcium and magnesium will be present in the effluent waters, whilst if the acidity is high aluminium will be brought into solution. The extent to which such dissolution takes place depends also on the local catchment characteristics. There will be strong seasonal variations due to flood and drought, with interaction with the soil and bed rock being least in the former and greatest in the latter. In addition there are likely to be pollution episodes where acid deposition exceeds general levels. These effects combine to give seasonal "spikes" of freshwater acidity, and similarly the concentrations of soluble metals will vary seasonally. It is these episodes of high acidity or of toxic metal content that may well be the main cause of ecological damage.

19. The correlation between acidity (or sulphate content) of freshwaters and their fishery status is neither simple nor direct. The calcium content of the water is clearly of crucial importance. This may be both because of its capacity to neutralise the free hydrogen ions that are the measure of acidity and its physiological importance. It appears able to protect fish from the toxic aluminium that is a feature of at least some acidified catchments. Whilst the detailed mechanisms are unclear, it is in this area that research seems most likely to provide an explanation of the processes behind the changes we are witnessing.

20. Another issue of debate is the timing of the onset of freshwater acidification. Evidence that the acidity levels of lakes and streams in geologically sensitive areas had been increasing in historical times and in line with increasing anthropogenic emissions of SO_2 and NO_x—would indeed be an important indication that acidic precipitation was an important contributing factor to freshwater acidification. Although some records show no increase in acidity of lakes over the last 20–30 years, the majority indicate that the acidity of freshwater lakes in geologically sensitive areas of Europe and North America has increased in this period. However, there are problems in the direct measurement of acidity (pH). In particular, doubt has been expressed on the reliability of the older data which were obtained using experimental methods now superseded. Even now there are problems in the accurate measurement of acidity in waters with low salt content, such as occur in rainfall and in many lake systems over the harder, older rocks.

21. Diatom analysis provides an important new method for studying acidification of lakes over relatively long time scales; this depends upon the observed relationship between the occurrence of different diatom species and lake acidity. Analysis of the relative numbers of the residues of such species in lake sediments allows estimates of lake acidity to be made as far back as 1800 AD. Sediment dating is undertaken by radiometric methods using 137 caesium or 210 lead. The experimental technique is skilled and specialist which limits its widespread utilisation, but the results appear reliable.

22. Such diatom analysis of lake sediments on resistant base-poor bed rock in N.W. Europe and North America show that acidification has indeed occurred in the last 150 years—that is since the start of the industrial revolution. For example the results obtained from four acid lakes in Galloway in South West Scotland show that the beginnings of acidification varied from ca 1840 for one lake to 1925 for another. Lake acidification was observed to commence before catchments were forested, so that the hypothesis that afforestation is largely responsible for the observed acidification does not appear valid in this instance.

23. It is thus likely that acidification of surface waters in sensitive hard rock regions is a reality and that such acidification will lead to damage of freshwater ecological systems.

This acidification appears to have developed over relatively long periods and the ecological effects are often uneven—a reflection of the complexity of the problem. There is no evidence to firmly link this freshwater acidification—and its associated biological effects—to any particular cause, although the circumstantial evidence is quite strong that acidic deposition of SO_2, NO_x and their oxidation products plays an important part. However, we are not in a position to say scientifically what degree of environmental benefit, if any, would result from any particular degree of emission abatement.

24. In Scandinavia liming of catchments has been adopted as a short-term remedy for freshwater acidification. This remedy has been able to sustain fish populations in at least some affected lakes—but not at the numbers present originally. It is considered by most active scientists in this field that it would not be practicable to use liming as a means of restoring conditions to those existing before freshwater acidification.

Health Effects

25. No direct effects of acid deposition on human health have been reported and generally ground level concentrations of SO_2, NO_x and particulates are below those considered to represent any risk to human health, although ambient levels are higher in urban than in rural areas.

26. It has been suggested that acidic deposition can so acidify freshwater systems that they can dissolve toxic heavy metals from the soil or containing media. A possible health risk could then result from the increased concentration of such toxic metals in the drinking water supply. Indeed, the dissolution of lead from plumbing systems can be a problem with acidic soft waters—as is the case in parts of Scotland and in some districts of England and Wales. Generally treatment of such waters with lime to reduce the acidity reduces the problem. The reason for the acidity of these waters is that they originate from naturally acidic peat uplands. There is no evidence that there has been any significant change in the catchment characteristics or in the quality of public water supplies since records have been maintained.

Effects on Materials

27. Corrosion of building and construction materials by acidic deposition, particularly SO_2 but also by NO_x, and their oxidation products, is a long standing environmental problem. It can be particularly severe in the case of galvanised metals and stone buildings constructed with alkaline rocks such as limestone; it can be a particular question of concern in the case of ancient monuments. Some UK coals contain significant quantities of chloride and the resulting chloride emissions can increase the rate of gaseous corrosion of metallic materials; the presence of marine salts in the atmosphere has similar effects. Generally rates of corrosion relate to the ground-level concentrations of such gaseous pollutants, and rates of corrosion decrease as ground level concentrations are reduced, but the relationship is not simple and other factors such as relative humidity and duration of wetness intervene. Although firm data are not available, the general indications are that metal corrosion rates in the UK have decreased since the early 1960s in line with the decreased ground-level concentrations of SO_2 (NO_x levels have held roughly constant over the last 10 years). However, corrosion rates are higher in industrial and urban areas than in rural areas.

28. Generally corrosion seems to be a local problem, depending upon the ground-level concentrations of SO_2 and other acidic species, the type of building material employed and the meteorological conditions. Thus anything which reduces such local concentrations of gaseous pollutants, such as reductions in emission levels or improving dispersion will reduce corrosion. Indeed improved dispersion through the use of high stacks has been of real advantage in this field.

Damage Costs

29. Estimates of the economic costs of these effects have been made by a few specialists, but must be considered as extremely uncertain. The most recent are those provided by Environmental Resources Ltd in a report to the European Commission. These figures relate to the community as a whole and are set out below:—

(a) loss of revenue from tourism and sport—£20m pa

(b) Five per cent loss of value of German forests plus limited further damage elsewhere—£200m pa

(c) loss of crop value as a result of the effects of ozone/SO_2/NO_x based on US experience and a little preliminary experimental work in Europe—£670m pa

(d) building costs based on OECD and ECE studies—£350–1900m pa

(e) costs of drinking water treatment in some areas—£14m pa

V RESEARCH ON ACID DEPOSITION AND ITS EFFECTS

1. Total spending by the Department of the Environment on air pollution research in 1984–85 will be £2.3m. Of this, about half will be concerned with monitoring and assessment of air pollution required to discharge Departmental responsibilities under UK legislation and in compliance with EC Directives. The remainder will be devoted to research, mainly into atmospheric chemistry and modelling, monitoring and measurement of deposition of acid components, and into effects of acidification. Details of the acid deposition research programme are shown in a Table printed in the HC 446–x.

Table 1 to Section V

DOE RESEARCH ON EFFECTS OF ACID DEPOSITION

CONTRACTS PLACED IN 1983–84

a. Effects of acid rain on upland soils and streams.
Macauley Institute £244,000 over five years

b. Chemical inputs from precipitation and their effects on the chemistry of a catchment area.
University of Loughborough £107,000 over five years

c. Effects of acidification on the fauna of lakes and streams in Scotland.
Department of Agriculture for Scotland £147,000 over five years (a substantial sub-contract has been let with Napier College, Edinburgh)

d. Combined impact of acid precipitation and ozone on vegetation.
Imperial College £14,000 in 1983–84

e. Effect of acid deposition on plants and soils.
Institute of Terrestrial Ecology, Edinburgh £513,000 over three years

(Sub-contracts to University of Lancaster on effects of SO_2 and NO_2 on trees, to University of Nottingham on effects of SO_2 on cereals, and University of Aberdeen on effects of acidic deposition on organic soils.)

2. The elements of the acid deposition effects programme for 1983–84 are shown in Table 1 to this section. Final details of the 1984–85 programme are still under discussion and Table 2 to this section gives a list of the proposals received for consideration. All the proposals cannot be funded from existing resources and it is likely that the projects asterisked in Table 2 to this section will receive the highest priority. Proposals 1, 2 and 9

Acid deposition extended research programme proposals 1984–85 onwards *Table 2 to Section V*

		Estimated cost UK					
Research proposal	Topic	1984–85	1985–86	1986–87	1987–88	1988–89	Total
*1. Welsh Office/WWA/ITE Bangor UWIST/Forestry Commission	Integrated Five (5) Catchment Study involving effect of afforestation and land management on water acidity, fish stocks and freshwater biota	109.5	93.0	69.5	53.0	53.0	378.0
*2. Freshwater Biological Assoc/NWWA/ITE Monks Wood	Integrated study of effect of modification on fauna (especially fish) and flora of Rivoro Duddon & Esk. Examination of remedial measures	100.0	125.0	70.0	70.0	70.0	435.0
*3. Imperial College	Effects of Air Pollution (including ozone) on Trees	67.3	58.3	58.3	—	—	183.9
*4. AERE, Harwell	Modelling of Acid Deposition	97.0	—	—	—	—	291.0
*5. EMEP Voluntary contribution	Modelling of Acid Deposition across Europe	10.0	10.0	—	—	—	20.0
6. NPL/BRS	Controlled Corrosion Studies on Economic Materials	50.0	50.0	50.0	—	—	150.0
7. Univ. of East Anglia	Long Term Changes in Acid Deposition Across Europe	35.5	38.8	42.0	—	—	116.3
8. Univ. of Lancaster	(i) Effects of Air Pollution on Trees (in collaboration with FRG, Switzerland)	6.5	6.5	—	—	—	13.0
	(ii) Role of Ammonia in Acid Rain	20.0	20.0	20.0	—	—	60.0
*9. Great Dun Fell Project ITE/Harwell/UMIST	Effect of Elevation and Occult Precipitation on Acid Deposition	20.0	20.0	20.0	—	—	60.0
10. Institute of Geological Sciences	Buffer Capacity of Soils	29.4	29.4	29.4	—	—	83.2
11. Institute for Marine Environmental Research	Acid Leaching from Soils	24.8	24.8	—	—	—	49.6
12. McCaulay Institute for Soil Research	Natural/Anthropogenic Sources of Acidity in Soils	61.7	62.4	62.8	—	—	186.9
13. Forestry Commission	Effect of Forestry Management on Acid Waters	—	60.0	—	—	—	60.0
14. Institute of Hydrology/UMIST	Snow Melt and Acidification	23.6	—	—	—	—	23.6
	Total	655.3	598.2	422.0	123.0	123.0	2115.5

Grand Total 1984–89, £1,921.5k

in Table 2 would extend the work on soils, forests and aquatic ecosystems already being carried out in Scotland into other sensitive areas of the UK.

3. In addition to the Department of Environment's research NERC spends some £0.7–0.9m a year and the Meteorological Office some £1.3m a year on relevant research. In addition, the CEGB spends about £1.0–1.5m a year on acid deposition research and, together with the NCB, has donated £5m over five years to the Royal Society to undertake a collaborative research programme with the Norwegian and Swedish Royal Academies of Science into the acidity of surface waters in Scandinavia.

4. Overall therefore, expenditure on research into acid deposition and its effects currently runs at some £4.5m a year in the UK.

VI EMISSION CONTROL OPTIONS

1. The following paragraphs describe broadly what is known about SO_2 and NO_x emission abatement techniques. There is only limited experience of the use of these techniques in the UK, and while the figures given in this paper are likely to be of the correct order, the full implications are likely to be known only when the techniques have been tested in full operation in UK conditions. All emission abatement methods, except for the use of naturally occurring low sulphur fuels, have the effect of altering atmospheric emissions into another form of discharge or effluent.

Abatement of SO_2 emissions

2. Broadly there are five routes which can be followed to achieve abatement of SO_2 emissions:—

(a) Use of low sulphur fuels
(b) Removal of sulphur from the fuel before combustion
(c) Capture of SO_2 immediately on its formation
(d) Removal of SO_2 from the flue gases after passage through the boiler
(e) Use of other technologies for power generation and the combustion of fossil fuel.

These options are summarised briefly in the following paragraphs.

(a) *Lower Sulphur Fuels*

3. About 80m tonnes of coal is used annually in power stations. Most of this is partially washed thereby removing some non-organic sulphur. The average sulphur content of power station coal used in England is about 1.6 per cent with some exceeding two per cent. Scottish and Welsh power station coal generally has a lower sulphur content averaging under one per cent. The 10m tonnes or so of coal used annually in other industries is, so far as practicable, cleaned, and the sulphur content tends to be lower than that of power station coal averaging about 1.2 per cent.

4. A sulphur emission reduction might be obtained by increased use of low sulphur coal. The amount of such coal available in the UK is limited. It occurs mainly in Scotland and Wales: Scottish deep mined coal is by far the most expensive produced and could hardly be significantly increased in the short term. Welsh coal would be more suitable but the NCB is already seeking to maximise Welsh coal production—difficulties are mainly practical. The increased mining and transport costs involved in bringing additional Scottish or Welsh coal to power stations outside those areas would be substantial.

5. Total emissions of sulphur dioxide from fuel oil combustion are about 0.85m tonnes. Use of low sulphur fuel oil would reduce these emissions to less than 0.30m tonnes (a reduction of about 14 per cent of UK total emissions and about seven per cent in emissions from power stations and other large plants covered by the proposed EC Directive—see Section VIII, paragraph 3). However, world supply of low sulphur fuel oils is subject to

constraints which in turn could have an impact on the additional cost particularly if there should be a widespread increase in demand among industrialised countries. For example, of the available low sulphur crudes most American supplies are used domestically; North Sea supplies are finite and are currently at their peak production level; and remaining supplies (Algeria, Libya and Nigeria) are currently subject to OPEC production ceilings.

(b) *Fuel De-sulphurising*

6. Sulphur is present in coal in two main forms. Part is chemically bound into the molecular structure of the coal and cannot be removed by physical means and part is present in mineral form—chiefly pyrites (iron sulphide). Coal cleaning carried out at collieries in order to reduce mineral impurities removes some of the latter; generally such washed coal has about 15 per cent less sulphur than that of mined coal. Further cleaning of all power station coal could reduce CEGB SO_2 emissions by about six per cent but at increased cost due to loss of coal in washeries and increased transport costs. It also seems likely that such action would cause disruption of the present integrated mine—power station delivery system with unknown consequential costs. In its evidence to the RCEP however the CEGB suggested that for a capital cost of £45–50m a reduction of nearly three per cent of its emissions could be achieved through additional coal cleaning and that the gross operating costs would be of the order of £10–20m per annum. NCB and CEGB are presently undertaking a joint study of the costs and other implications of further cleaning and it is hoped that the results of this study will be available in the middle of the year.

7. Advanced coal cleaning methods are being developed in the FRG and are thought to be removing some 25 per cent of sulphur, but detailed figures have not been published. The composition of coal differs widely and direct comparisons cannot necessarily be made with the UK situation.

8. If low sulphur fuel oils were not available on the market the oil industry say that it would be possible to de-sulphurise oil at a cost of £680–1,585 per tonne of sulphur dioxide abatement. This would represent a cost of about £280m–£650m to achieve a reduction of about seven per cent in large combustion plant emissions.

(c) *Immediate Sulphur Capture*

9. The best known example of this process is the addition of powdered limestone to fluidised-bed combustors. In the fluid bed the limestone disassociates into free lime which reacts with the SO_2 produced to give calcium sulphate which is removed along with the coal ash and in the dust collected in the flue gas cleaning equipment.

10. The feasibility of the atmospheric limestone/fluidised-bed combustor has been demonstrated experimentally on small scale plant, but there is little operational experience in the UK or elsewhere, and some important operating questions remain to be answered. For example, the continuing sulphur removal efficiency in relation to the limestone used is not known, nor is there any information on the effect of the presence of calcium sulphate and free lime on disposal options for the combustor ash and the collected flue dust in view of the occupational hazards associated with handling these materials. Several small atmospheric fluidised beds are in operation in the UK.

11. The development of low NO_x burners which generally reduce flame temperatures has provided an impetus for experiments on direct limestone injection. However, costs may be high and in excess of those for conventional flue gas cleaning techniques, and there could be further problems of disposing of waste.

(d) *Removal of Sulphur from Flue Gases*

12. The most common processes use a limestone slurry to absorb the SO_2 from flue gases. In their simplest form such flue gas desulphurisation processes (FGD) convert the SO_2 to calcium sulphite with only a small proportion being oxidised to calcium sulphate

(gypsum). The crystal form of the calcium sulphite makes it difficult to de-water so that the product usually has to be disposed of as an emulsified sludge. Adoption of this technology leads to a waste disposal problem in place of an air pollution problem.

13. The FGD process can be modified, at some increase in cost so that the calcium sulphite can be completely converted to gypsum. This product can be readily de-watered, so simplifying disposal. There is a possibility of some of the gypsum being used for manufacture of plasterboard subject to the quality of the material. But the extent to which this could take place would depend on market conditions and any gypsum which could not be used to manufacture plasterboard would have to be disposed of as waste.

14. An alternative system is the Wellman–Lord process in which the flue gases are scrubbed using sodium sulphite solution; the latter is continuously re-generated within the process to give a nearly pure SO_2 product. This can be converted into sulphuric acid or elemental sulphur by reaction with natural gas. The process is more expensive in energy use than limestone scrubbing, but it does have the advantage of providing a useable product. It is unlikely however that there would be use for the product from more than two power stations.

15. The costs of FGD under UK operating conditions are reasonably well established in respect of power stations. The CEGB estimate that retrofit of a Wellman-Lord process (the most expensive) to an existing 2000 Megawatt power station would cost of the order of £150m capital with about £25m a year running costs (excluding capital charges). The same process applied to a new power station of similar size would cost about £120m, also with running costs of about £25m a year. A number of problems, including those associated with waste disposal, have yet to be resolved and could perhaps be resolved only in practice. It should be noted that there is no significant experience of the use of FGD in association with industrial boilers which are generally much smaller than those in power stations. The additional cost of FGD in such cases would be likely to be relatively much higher.

(e) *Alternative power generation and combustion of fossil fuel*

16. Energy conservation, nuclear generation and use of renewables would result in reduction in SO_2 (and other) emissions. The implications of these alternatives are not considered in this paper.

17. In principle emission control advantages can be obtained from pressurised fluidised beds which might be used in combined cycle power generation systems. Similar advantages might also be obtained by gasifying coal for use in a combined cycle power generation system. Application of these systems to power stations is only at the preliminary design stage and there is as yet no relevant operating experience.

Abatement of NO_x emissions

18. There appear to be two routes to achieve abatement of NO_x emissions:

(a) by combustion modifications,
(b) by removal of NO_x from the flue gases.

(a) *Combustion Modifications*

19. There are a number of techniques under this head which are in use in Japan and the USA. Broadly, they fall into three categories: Modification of combustion conditions, modification of the combustion facility itself, and low-NO_x burners. Of these low-NO_x burners may be the best option. There is as yet no experience of these burners in UK operating conditions but the CEGB is studying the technique. The cost of retrofitting low-NO_x burners to a 2,000 MW power station would be of the order of £10m per station.

20. For large combustion units, flue-gas de-nitrification has been installed in a few cases in Japan. This technique can achieve high emission reductions (c 90 per cent) but for

capital investment and running costs of a similar order to that of FGD. There may also be significant environmental problems which have yet to be fully overcome with this technique.

Other industrial combustion plants

21. Although the previous paragraphs contain a few references to other industrial plants, most of the discussion has related to power station boilers. Experience of application of SO_2 and NO_x controls to other combustion plants is limited in the world as a whole and non-existent in the UK although there is experience in controlling emissions from sulphuric and nitric acid plants. The costs of sulphur controls in relation to the costs of the plant are likely to be higher than the costs for much larger power station boilers and the use of low sulphur fuels or gas would appear to be the main way in which these emissions can be reduced. In the case of NO_x there is experience in the USA and Japan of applying combustion modifications and similar modifications might be applicable in the UK, but it should be noted that most US and Japanese experience relates to oil-fired boilers. It is possible that the fitting of low NO_x burners in new plants would not give rise to any additional cost, but retrofitting is likely to give rise to problems similar to those which would arise in power stations.

VII UK RESEARCH ON CONTROL TECHNOLOGIES

1. Research in this field is primarily a matter for industry although with some pump priming from Government. The CEGB and, to a lesser extent, the NCB fund a range of projects and the Departments of Energy and Trade and Industry lend support to some relevant work. The Department of the Environment has no direct involvement. In addition, development of combustion technologies is carried out by a number of companies in the private sector but for reasons of commercial confidentiality little is known about this work.

2. A list of some current projects on fuel treatment, combustion technology and control techniques which are all directly concerned with reduction of emissions is at Table 1 to this section.

3. In addition, research on energy efficiency and conservation and on renewable sources of energy, although not primarily related to emission reduction, may lead to a decrease in use of fossil fuels and hence in emissions. The Government is spending over £25m a year on energy efficiency and conservation and some £11m a year on renewables. The CEGB, British Gas, NCB and private industry are also spending large sums in these areas of research.

Table 1 to Section VII

RESEARCH ON FUEL TREATMENT, COMBUSTION TECHNOLOGIES AND EMISSION CONTROLS

Fuel treatment	
Rig trial of high gradient magnetic separation of coal	£150k
Pilot combustion trials of cleared coal	£6m
Study of coal water mixtures as a low sulphur replacement for oil	£m several
Combustion technology	
Study of pressurised fluidised bed. Combustion combined cycles as a high efficiency system for the 1990s with built in sulphur retention	£25m
Study of low NO_x burners	£4.5m
Emission controls	
Assessment of Wellman-Lord FGD process	£85k
Engineering assessment of limestone/gypsum FGD process	£45k
Pilot installation of chlorine pre scrubber needed to prepare UK coals for FGD systems	£200k

VIII INTERNATIONAL ASPECTS

1. Acid deposition first aroused public concern in Scandinavia in the 1960s. It was the subject of a Swedish report to the United Nations Conference on the Human Environment in Stockholm in 1972. In the late 1970s, Scandinavian Governments responded to a proposal by President Brezhnev for a conference on the environment within the CSCE framework by pressing for "acid rain" to be the main item on the agenda. As a result the Convention on Long Range Transboundary Air Pollution (LRTBAP) was signed by member countries of the United Nations Economic Commission for Europe in Geneva in 1979. The Convention reflects the British preference for exchange of information, monitoring and research as a basis for development of strategies and policies to combat air pollution. The Convention was implemented on an interim basis from 1979 and came formally into force in March 1983; the Executive Body met for the first time in June 1983.

2. Scandinavian dissatisfaction with progress under the Convention led the Swedish Government to convene a conference on acidification in Stockholm in June 1982. This conference greatly increased political awareness of the problem and was notable for a radical change in the position of the Federal Republic of Germany, which had previously been broadly similar to that of the UK. The FRG announced plans for stringent measures to reduce SO_2 emissions because of recently discovered damage to their forests. These measures were introduced in new legislation on 1 July 1983 and will require retrofitting of controls to 200 plants.

3. The Conference was followed by increasing activity in the Community. Two proposals for directives were drafted in late 1982. The first, a general directive on the combating of air pollution from industrial plants, was agreed at a meeting of the Council of Environment Ministers on 1 March 1984. It is a framework directive which provides for the prior authorisation of industrial plants likely to give rise to air pollution and makes provision for the Council, if necessary, to fix Community-wide emission limits. The second, a directive which would require the imposition of controls on emissions of sulphur dioxide, nitrogen oxides, and "dust" (more usually described as particulates) from large combustion plants (including power stations), was passed in draft by the Commission to the Council in January 1984. The Council has yet to discuss this proposal and the Government's response to it is presently under consideration.

4. The problem of acid deposition was raised at meetings of the European Council in March and June 1983. In March the Council concluded that damage to the forest environment made action on acid rain urgently necessary. In June the Council again stressed the need for urgent action against pollution, in particular because of forest damage, and called on the Commission to pursue relevant initiatives with a view to "rapid significant progress". The Commission regard the "large plants directive" as their prime response to this call, but have also proposed, or intend to propose, a number of other relevant initiatives.

5. At the first meeting of the UN/ECE Convention's Executive Body in June 1983 a number of countries (including the Scandinavian countries, the FRG and Canada) pressed other signatories to agree to reduce SO_2 emissions by 30 per cent by 1993, based on 1980 levels. This proposal was too specific for most participants in the Executive Body meeting, including the UK, who committed themselves instead to the necessity for an "effective" reduction in emissions by 1993.

6. International political interest has continued during 1984. The European Parliament has passed a Resolution calling for a number of actions to combat acid deposition and air pollution generally. The Council of Europe Assembly has recommended that a COE Convention on Acid Rain and Air Pollution should be negotiated. At the end of March the Canadian Government convened a meeting in Ottawa of Environment Ministers from countries which are committed to reducing SO_2 emissions by 30 per cent and this meeting called on other countries to do likewise and also reduce to NO_x emissions by an unspecified amount. The Government of the Federal Republic of Germany have invited signatories of the LRTBAP Convention to a high-level conference in Munich in June to discuss air pollution in general with a view to gaining general agreement to more stringent emission control policies based on available (not necessarily economically feasible) technology. In

September the second meeting of the Executive Body of the LRTBAP Convention will be held in Geneva.

7. In addition a number of other international organisations are undertaking work that is intended to contribute towards action on acid deposition. These organisations include the Organisation for Economic Cooperation and Development (OECD), the International Institute for Applied Systems Analysis (IIASA), the NATO Committee on Challenges of Modern Society (CCMS), and several UN/ECE subsidiary bodies concerned, for example, with Timber, Electricity, Scientific Research, Inland Transport.

IX UK CONTROL LEGISLATION

(a) *Legislation in force*

1. Emissions of SO_2 and NO_x from the largest industrial sources (fossil-fuelled combustion plants including power stations) are controlled by the Industrial Air Pollution Inspectorate in England and Wales and by parallel Inspectorates in Northern Ireland and Scotland (the Inspectorates). The Inspectorates also control SO_2 and NO_x emissions from non-combustion sources. Emissions of these gases from other combustion plants are a matter for local authorities (LAs).

2. Section 5 of the Health and Safety at Work etc Act 1974 imposes a duty on operators of industrial processes included in the schedule of processes within the control of the Inspectorates to use the best practicable means (bpm) to prevent emissions into the atmosphere of noxious or offensive substances and to render harmless and inoffensive such substances as may be emitted. In enforcing this duty, the Inspectorates interpret the term "practicable" as incorporating both technical and economic feasibility, and they apply the duties to prevent and render harmless in sequential fashion: the first requirement is to prevent emissions and the second if that is not practicable, to render them harmless. In the case of SO_2 and NO_x emissions from combustion processes, prevention, or partial abatement, has hitherto been regarded as impracticable on grounds of cost, and operators are therefore required to render ground-level concentrations of the emissions harmless by dispersal from high stacks and dilution in the air. Abatement of grit and dust emissions is however required.

3. In the case of non-scheduled combustion plants, LAs in England, Wales and Scotland enforce provisions of the Clean Air Acts 1956 and 1968 which require arrestment of grit and dust emissions from furnaces. They also approve the height of industrial chimneys within guidelines laid down by the Government which take account of the need to disperse SO_2 and NO_x emissions to render them harmless. LAs also exercise the statutory nuisance powers of the Public Health Act 1936 by virtue of "which they may, by order enforceable in the Courts, require the abatement of any emissions which are injurious to health or a nuisance". LAs in Northern Ireland rely on powers similar to the Clean Air Act powers, together with nuisance legislation.

4. Under both forms of control therefore grit and dust emissions have to be abated while SO_2 and NO_x emissions have to be dispersed. In the case of the Inspectorates powers to require abatement of SO_2 and NO_x emissions are available in the form of the discretion of the Inspectorates to determine what constitutes bpm.

5. In addition to powers to control emissions, there is also a power under Sections 75 and 76 of the Control of Pollution Act 1974 enabling the Government to regulate the sulphur content of oils by order. Two orders have been made regulating respectively the sulphur content of diesel fuel used in vehicles and of gas oil used in domestic and commercial furnaces. No order has been made to regulate the sulphur content of fuel oil, which is mainly used in industry, except for a special order applying to the area of the City of London.

6. Before the CEGB can construct or extend a power station, it must apply to the Secretary of State for Energy for consent under section 2 of the Electric Lighting Act 1909

as amended. Consents for coal-fired power stations usually include the following condition:

> "the layout of the [power station] shall be designed so as to permit the installation of such plant as may be reasonably practicable for the prevention of the discharge of sulphur and its compounds into the atmosphere, and the Board shall, if so required at any time by the Secretary of State, install such plant."

7. Finally, an EC Directive is in force which sets air quality limit values for SO_2 and smoke for the purposes of health protection. Data derived from country-wide monitoring indicates that the Directive's value for SO_2 is not exceeded in the UK. If the limit value were to be breached however, it would be necessary to take action to control SO_2 emissions in the area in which the breach occurred.

(b) *Legislation proposed or in preparation*

8. On March 1984, the Council of Environment Ministers agreed (subject to a parliamentary reserve by the UK) a directive on combating air pollution from industrial plants, which will come into force in late 1987. This Directive will require Member States to ensure that specified plants likely to give rise to air pollution will be subject to prior authorisation. The specified plants include combustion plants of 50 megawatt thermal output and above. The Directive also requires that authorisation should be granted only when the competent authorities are satisfied that the plant in question will not give rise to significant air pollution and that appropriate preventative measures including the application of the best available abatement technology which does not give rise to excessive costs (ie bpm) will be taken. Finally, the Directive includes provision for the Council, if necessary, to fix Community-wide emission limits. The implications of the Directive are being studied but it is thought that in relation to combustion plants alone, the powers described in paragraphs 2 and 3 are adequate to ensure compliance. New legislation will, however, be required for full compliance with the Directive since it applies to some other types of plant giving rise to emissions other than SO_2 and NO_x.

9. Another directive, which would require control of emissions of SO_2, NO_x and particulates from large combustion plants, was passed by the Commission to the Council early in 1984. This would apply to all combustion plants of 50 mw thermal output and above and would impose limits on emissions of SO_2, NO_x and particulates from new plants. It would also require Member States to reduce total emissions of SO_2, NO_x and particulates from the category of plant covered by the Directive, by 60 per cent, 40 per cent and 40 per cent respectively by 1995 on the basis of the 1980 mean level of emissions. The Government is considering the implications of this proposal.

10. The European Commission is understood to be studying the possibility of introducing a proposal to limit the sulphur content of fuel oil and possibly of coal throughout the Community.

11. In the field of air quality, the Council has under consideration a proposal by the Commission to set limit values for nitrogen dioxide (NO_2). The scientific basis for this Directive is less sound than that for the SO_2 and smoke air quality Directive. If the Directive is adopted and comes into force however, specific action to control NO_x emissions will be required if the proposed limit value is breached.

12. The Government, as indicated in response to the fifth report of the Royal Commission on Environmental Pollution, has undertaken a comprehensive review of the air pollution control legislation which applies in England, Wales and Scotland. A consultation paper is being prepared. A review of air pollution control legislation is also being undertaken in Northern Ireland.

ANNEX

This Annex represents the views of the Department's Scientific Adviser

Chemical transformations in the Atmosphere and their role in Acid Deposition

Dr A E J Eggleton

Understanding the problem of acid deposition requires knowledge of the relationship between pollutant emissions and deposition of the resulting acidity on the earth's surface, both of which are functions of time and space. Before being deposited, a substantial fraction of the primary pollutants, sulphur dioxide (SO_2) and nitric oxide (NO) are converted into the respective secondary pollutants, sulphuric acid (H_2SO_4), nitrogen dioxide (NO_2) and nitric acid (HNO_3). The acids further react to form their ammonium salts which form a fine particulate aerosol. Each of these species is deposited by different mechanisms or at different rates, so that the pattern of deposition from any given source of a primary pollutant is a complicated function of meteorological factors (which determine pollutant transport), chemical conversion rates in the atmosphere (which depend on the presence of yet other pollutants) and deposition mechanisms. Thus while it is axiomatic that those acidic pollutants which are emitted to the atmosphere must come down to earth or ocean somewhere and in some form (since there is no long term build-up of sulphur or nitrogen compounds in the atmosphere), the detailed distribution of their deposition is a matter of considerable complexity. It is by no means certain that a reduction in primary emissions would be accompanied by a corresponding linear reduction in deposition at any particular location. Equally, changes in the emissions of other pollutants which take part in the chemical transformation of the primary pollutants may have important effects. These considerations are the basis of the so-called non-linearity hypothesis.

In general terms the gaseous primary pollutants are deposited by direct absorption on the earth's surface, by the so-called "dry deposition" process, whereas the secondary pollutants such as sulphuric and nitric acids and their salts are also deposited in rain, so called "wet deposition". Apart from the slight acidity due to dissolution of natural carbon dioxide, virtually all the acidity of rain is due to secondary pollutants. Thus chemical conversion of primary pollutants in the atmosphere is a necessary pre-condition for the formation of "acid rain", though not for the dry deposition process which, averaged over the whole area, contributes about equally with acid rain to the total acid deposition. On the other hand, dry deposition is a more important contributor to the acid deposition at places close to the source of pollutants whereas acid rain contributes a larger fraction at more distant places. Dry deposition is basically a continuous process whereas wet deposition is episodic, depending on the occurrence and amount of rainfall. Thus places with greater than average rainfall, such as hills in the western areas of Britain or Scandinavia, receive proportionally more acid deposition than do neighbouring lower-lying areas. Further discussion of deposition processes is contained in a later section.

The nature and mechanisms of the chemical processes by which primary pollutants are converted to secondary species in the lower atmosphere are very complex and still not completely understood. Until about 20 years ago it was thought that the oxidation of sulphur dioxide to sulphuric acid was due to atmospheric oxygen and occurred mainly in water droplets, catalysed by trace amounts of metals such as manganese and iron, emitted mainly from coal-burning.

However, it is now recognised that there is insufficient of the metal catalysts present in all but the most polluted air for this process to account for the rates of oxidation actually observed. Instead, the development of atmospheric chemistry over the last 20 years has demonstrated the importance of highly reactive free radicals in the oxidation processes and revealed a link with another major form of pollution, photochemical smog.

The processes leading to the formation of photo-chemical smog take place when mixtures of hydrocarbons and nitrogen oxides are exposed to sunlight. Motor vehicle emissions are a major source of these two pollutants though there are also substantial contributions from refineries and petro-chemical works in the case of hydrocarbons and stationary combustion sources, including power stations, for nitrogen oxides.

In simplified terms the gases take part in a cyclic process in which hydrocarbons react with hydroxyl radicals resulting in the conversion of nitric oxide to nitrogen dioxide and the regeneration of hydroxyl radicals to carry on the cycle. The nitrogen dioxide is dissociated by sunlight into nitric oxide, which returns to the cycle and an oxygen atom which combines with ordinary oxygen to form ozone, a major deleterious constituent of photo-chemical smog. The hydroxyl radicals necessary to start the reaction are formed by the action of sunlight either on ozone already present (from previous pollution or natural sources) or on some of the minor constituents of vehicle exhaust, such as aldehydes. Apart from exhaustion of the hydrocarbons or removal of sunlight, the cycle can also be terminated by the loss of free radicals by reaction with nitrogen oxides to form nitric acid which takes no further part in the cycle. Thus photo-chemical pollution is essentially a process fuelled by hydrocarbons and sunlight in which nitrogen oxides have both a catalytic role as part of the cycle and also act as a means of cycle termination. The significance of this dual role for nitrogen oxides will become apparent later when the effects on acid deposition of reducing nitrogen oxide emissions is considered.

From the view-point of sulphur dioxide oxidation, photo-chemical pollution plays the essential role of providing a source of hydroxyl (and hydroperoxyl) radicals plus hydrogen peroxide and ozone, all of which are capable of converting sulphur dioxide to sulphuric acid. The oxidation occurs by two general mechanisms, either entirely in the gas-phase by reaction with free radicals to form a fine aerosol of sulphuric acid (or if neutralised, ammonium sulphate), or by reactions with hydrogen peroxide and ozone in fog or cloud droplets to form acid rain directly.

The evidence for the existence in the atmosphere of this complex structure of chemical processes derives from a large body of laboratory research and atmospheric measurements carried out both within the UK and in other countries. Although knowledge of these processes is fairly comprehensive, it is none the less still incomplete. Simply as an illustration, evidence is included in Fig. 1 which shows the formation of sulphuric acid at Silwood Park during a photo-chemical episode in 1972. The close correspondence between the peak in photo-chemically produced ozone (O_3) and of the sulphuric acid (H_2SO_4) shows that the latter is produced in the same process as the former. The figure also demonstrates the corresponding increases in nitrate and sulphate. Note that the sulphate (SO_4^{2-}) curve includes ammonium sulphate as well as sulphuric acid.

The maximum rate of oxidation of sulphur dioxide to sulphuric acid by entirely gas-phase mechanisms is calculated to be about 2 per cent per hour in full summer sunlight in NW Europe, leading to a typical lifetime for SO_2 of 10 days before conversion if there are no other processes resulting in its removal. Oxidation in cloud droplets is thought to be much more rapid, though this is an area where scientific knowledge is less complete. Calculations based on known reaction rates and a very few observations in real clouds suggest that SO_2 oxidation would be complete in a few minutes provided sufficient free radicals and oxidising agents are present. This will depend on the concentration of hydrocarbons and the extent of photo-chemical activity at the time.

It will be seen that the complexity of the chemical transformations, the variability of meteorological factors which affect both atmospheric transport and the amount and location of rainfall, make the assessment of the distribution of acid deposition arising from any given source, collection of sources, or from any one country, an extremely difficult matter. This problem can only be addressed by the construction of mathematical models. Although this has been done on a limited scale, for example in the OECD study of the Long Range Transport of Atmospheric Pollution, so far most models have only attempted assessment of long term average deposition. Since there is evidence that at some sites most of the annual acidity is deposited in only a few rainfall episodes and because only simple atmospheric chemistry has generally been used, the models are not yet sufficiently sophisticated to make predictions of the changes in deposition expected from reductions in emissions. Most attention has so far been given to reductions in emissions of sulphur dioxide, and the importance and consequences of reductions in the emissions

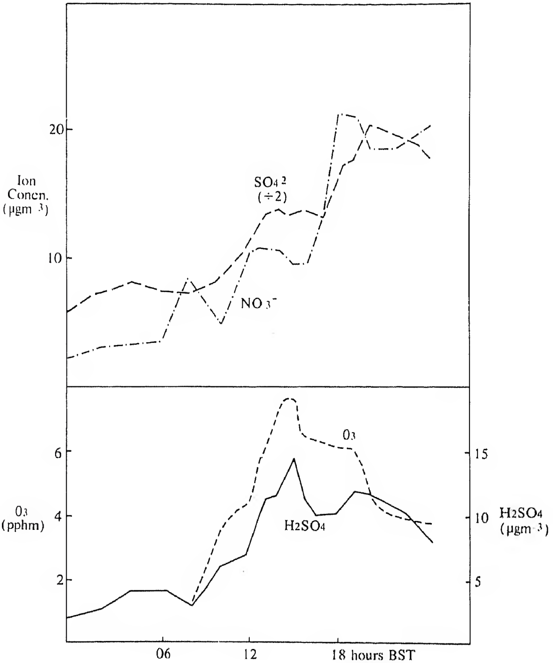

FIG 1
Photochemical Episode Silwood Park Sept 6th 1972

of other pollutants on deposition in sensitive target areas is only now being addressed by the scientific community.

Until recently, both knowledge of atmospheric chemistry and the scope of mathematical modelling techniques have been inadequate for quantitative assessments of this complexity. The situation is now changing and there are several research groups tackling these problems, notably in the USA. In this country the Department of the Environment is funding the development of such a mathematical model at the Harwell Laboratory starting in April 1984. A particular problem to be considered is the effects of reduction in emissions of nitrogen oxides. It is by no means certain that these would be universally beneficial. It was earlier noted that nitrogen oxides play a dual role in the development of photo-chemical pollution. On the one hand they form an essential link in the cycle involving free radical production but on the other they act to remove free radicals from the system. It turns out that the concentration of nitrogen oxides needed to sustain the free radical cycle is small, much less than that found normally in polluted atmospheres. The dominant role of nitrogen oxides is therefore one of limiting the photochemical reactions. Thus the immediate effect of reducing nitrogen emissions is to increase the intensity of the photochemical process and enhance the formation of ozone. Reductions in nitric acid deposition resulting from reduced emissions of nitrogen oxides could well be offset by increased deposition of sulphuric acid at some locations arising from enhanced free radical oxidation of sulphur dioxide. Only with reductions in nitrogen oxide emissions of greater than 90 per cent is it expected that there would be a fall in photochemical activity.

Conversely, even limited reduction in hydrocarbon emissions would cause an immediate reduction in both free radical concentrations and in the corresponding oxidation rates of both sulphur and nitrogen oxides. Clearly, reducing nitrogen oxide emissions may not be a cost effective route to reducing acid deposition. Furthermore, recent evidence suggests that some of the damage previously attributed to acid deposition, for example in German forests, may instead be due to photochemically produced ozone. Reduction in emissions of nitrogen oxides could well sustain or even exacerbate such damage by increasing ozone concentrations.

Deposition processes

These are of central importance in determining where pollutants end up, and hence, where, and with what intensity, effects may occur in soils, vegetation and surface water.

Deposition is divided into wet and dry:

Dry deposition consists of direct absorption of gases, or collection of particles, by vegetation, soil or water surfaces. About a half of the SO_2 emitted into the atmosphere can be removed by dry deposition in 30 h, during which time typical wind speeds would have carried the remainder about 1,000 km. Dry deposition of sulphate particles is much slower. Dry deposition of NO_x has received less attention and is less well quantified. It probably is comparable with SO_2 deposition. Dry deposition of HNO_3 is probably more rapid and PAN is also removed by dry deposition, but the relative importance of various removal routes for NO_x and its oxidation products are not yet well established. Dry deposition of SO_2 to the sea surface between Britain and Scandinavia may sometimes be important in reducing the pollution load reaching that region, but often the sea surface is colder than the air above, suppressing mixing and effectively preventing significant deposition.

While dry deposition is a continuous process, acting only at the surface, wet deposition intermittently cleans the atmosphere to a great depth. Individual episodes can occasionally deposit large amounts of acidity (amounting to a significant fraction of the annual total) in periods of a few hours. The most acid rain usually occurs when rainfall is moderate or light and occurs most often in regions (eg Eastern Britain) where such rain is common. Heavy rain dilutes the acidity but may deposit a greater acid load. This occurs eg in W. Scotland. Rain probably removes most sulphate and nitrate particles from the atmosphere, by a process involving condensation of water onto such particles in cloud, to form the cloud drops which coallesce to form rain. Chemical processes, oxidising SO_2 and NO_2 within cloud droplets, can probably remove these gases efficiently as well.

A third process, of fog interception or occult deposition, is normally included in dry deposition, and is probably significant in some upland areas. Like cloud, fog forms dry condensation of water onto particles, including sulphate and nitrate. These droplets, much larger than the original particles, are filtered efficiently from the air by vegetation. Forest and, to a lesser extent, grass and heath, may collect significant amounts of acid species in this manner. Some uplands are frequently shrouded by hill fog, accompanied by moderate or strong winds. For such areas the deposition in this form may be comparable or greater than that in rain. Often the concentration of sulphate and nitrate in the fog or cloud water is much higher than that in rain. Thus foliage may be subjected to rather high concentrations in such episodes. This is another area which has as yet received inadequate attention.

Measurements make it possible to obtain a general understanding of deposition and transport of sulphur emitted to the atmosphere. About one-third of the S emitted in Britain is deposited within the country. Over W. Europe the larger area leads to a larger fractional deposition before the wind carried the pollution away, and 60 to 80 per cent is deposited. One half or more of the deposition is dry deposition. Similar rates probably apply to NO_x and its derivatives.

ADDITIONAL PAPER PREPARED BY THE BUILDING RESEARCH ESTABLISHMENT (DOE)

Effects of Acid Precipitation on Buildings

Dr L H Everett

1. *Decay of Stone.* There are many factors which contribute to the decay of stonework in modern and in historic buildings. Only some of these factors are enhanced by increased levels of acid pollution. In the British Isles the major cause of stone decay is crystallisation of salts within the pores of the stone, a process which generates sufficiently large stresses to cause local fragmentation. The salts may get into the stone in several ways, one of the more important being the ultimate production of calcium or magnesium sulphate by reaction of limestones or magnesian limestone with sulphur dioxide dissolved in rain water.

The presence of calcium sulphate is normally indicative of acid deposition attack but under some conditions sulphate may be introduced into the stone by other means, such as rising damp, use of unsuitable stone cleaners, sea water or chemical sprays. The action of acid sulphur gases on calcareous materials causes hard, impermeable surface skins to form which blister and exfoliate. These surface layers are mainly calcium sulphate and tend to be most harmful in sheltered areas where the rain cannot wash away the sulphate coating. Exfoliation, blistering and general disfiguring of stone in buildings is related to such factors as the relative thermal expansion of the stone and the by-products formed by the pollutant, the porosity of the stone, the temperature and humidity cycling, and crystallisation and recrystallisation of salts such as calcium sulphate within the stone. The precise contribution of acidic deposition towards the deterioration of stone is therefore difficult to distinguish among the other contributory factors.

The real threat of acidic rain or other deposition lies not in its direct chemical attack on stone but in the production of calcium sulphate. The calcium sulphate, being slightly soluble in water, can cause crystallisation damage; whereas attack by acid rain is a once and for all chemical conversation, crystallisation attack occurs over and over again.

The importance of crystallisation attack over acid attack is demonstrated by the fact that some limestones weather very much faster than others. If acid attack were the predominant factor, all limestones would weather at much the same rate. The marked differences in durability that occur in practice are due to differences in the shape and size of the pores within the stone, for it is these properties which determine a stone's resistance to crystallisation attack.

The predominant influence of crystallisation attack, which requires cycles of wetting and drying, also explains why the decay rate of any given limestone is not directly in proportion to the amount of acid gases in the air. Between 1955 and 1965, the Building Research Station compared the behaviour of specimens of Portland stone that were exposed at Garston and at Westminster. The amount of sulphur dioxide in the air at Westminster ranged from five to 12 times as much as that at Garston, but the Westminster specimens lost weight only two and a half times faster than the Garston specimens. Amongst other things, this means that the introduction of further controls on sulphur oxide emissions would not necessarily have a significant effect in reducing the rate at which limestone in existing buildings decayed. Even if the emissions could be stopped altogether the calcium sulphate that had already formed in the stone would ensure some continued deterioration.

There is however as yet little quantification of the effects of the different variables listed above on stone or most other building materials.

2. *BRE Work Related to Acid Deposition.* The Building Research Establishment has maintained a continuing interest in the decay and conservation of stone masonry over a long period. One of the earlier reviews on the topic was issued in 1938 and a facsimile edition published by HMSO in 1972 "The weathering of natural building stones". Updated reports were published in 1975, in a BRE Digest (177) "Decay and conservation of stone masonry" in May 1975, and in 1979. As part of the overall research programme on stone, methods of preserving the fabric of stone buildings were investigated, reported in the HMSO document "Stone preservation experiments" and led to the eventual development of a patented silane-based stone preservative "Brethane". A technical appraisal of stone conservation techniques employed at Wells Cathedral was published in 1983.

A project of the Department of Geography, University College, London, sponsored by BRE, has examined the condition of the external stonework on St Paul's Cathedral, in particular the balustrade erected in October 1717. This balustrade was constructed of Portland stone, the blocks raised into position by a pulley system using holes drilled through the stone to secure the hoisting rope. After positioning these holes were partially filled with waste and the filling completed by pouring in molten lead up to the stone surface. The top of each lead plug therefore marks the original surface of the stone and enables an assessment to be made of the rate of decay of the stone since construction. Examination shows that the plugs now stand proud of the surface by 8–30 mm. The erosion rates on each quadrant (NW, SW, SE, NE) have been measured and give a mean erosion rate of 0.078 millimetres per year. There is a significant difference between the lower rate of erosion from the NE orientation than from the other three quadrants. This data has been published in Earth Surface Processes and Landforms, Vol 7, 1982.

A guide to the currently available building limestones of the British Isles, including their durability, locations and sizes of quarries, and reference buildings where they can be seen, has been published (The Building Limestones of the British Isles, HMSO, February 1984). This guide follows on from an earlier publication (HMSO, 1982) "The building limestones of France" which gave similar information on French limestones often imported into the UK for renovation work.

3. *Current and Future Work at BRE.* Current BRE research on stone selection, durability and preservation has resulted in three major studies being undertaken. One was on the weathering of stone at St Paul's Cathedral (including the effects of pollutants), another on spatial variations in stone weathering and air pollutants in SE England and a third on the weathering of stone at Wells Cathedral. The results of the first two studies are being assessed and PhD theses are nearing completion; the third study is current and will be complete in about 18 months' time. Concomitant with the above, BRS participated in a NATO/CCMS exercise in which the atmosphere at fixed points on buildings of historic significance was sampled (for subsequent analysis) simultaneous with samples of stone exposed to weathering at the same locations. In the UK these were St Pauls Cathedral, Westminster Abbey, Dunstaffnage Castle (Scotland). The locations were mainly in Europe with some in North America. Preliminary meetings have been held to discuss results. Experience related to the monitoring of the atmosphere around ancient monuments is to be presented at a NATO science foundation meeting in Rome in June. Other collaborative studies with CEGB of the exposure of stone and concrete samples are underway.

Considerable initiative on the effects of acid precipitation on buildings and building materials is being taken in Europe by the EEC and the UNECE (to whose convention on transboundary air pollution the UK is a signatory). BRE is already involved in the

UNECE expert Working Group on the effects of sulphur dioxide (and other pollutants) on the environment; and it is anticipated that parts of a new BRE programme will integrate with proposals for UNECE research. BRE has proposed case studies at Bolsover Castle in Derbyshire (an area of high pollution) and further studies on Wells Cathedral for EEC funding.

The new BRE programme will include laboratory tests on the effect of pollutants on a wide range of building materials, site studies of exposed samples and existing buildings and assessment of different materials and types of building at risk. BRE will be working in collaboration with Government and other bodies both in the UK and in Europe. The main aim will be to derive quantitative "dose-response" data for materials and pollutants to feed into cost/benefit analyses.

Examination of witnesses

DR M W HOLDGATE, Chief Scientist and Deputy Secretary, Environmental Protection; DR D A EVEREST, Chief Scientific Officer, Central Directorate of Environmental Protection; MR P D BURGESS, Principal, MR R B WILSON, Principal Scientific Officer, Air and Noise Division; DR A E J EGGLETON, Atomic Energy Research Establishment, Harwell, Scientific Adviser; DR L H EVERETT, Senior Principal Scientific Officer, Building Research Establishment; and MR A SINFIELD, Economic Adviser, Environmental Protection Statistics and Economics Division, called in and examined.

Chairman

160. Good afternoon, Dr Holdgate. May I thank you all first of all for the paper that you have submitted to us in advance. I personally have found it a very helpful paper in as much as it encapsulates many of the problems with which we have been concerned, and also, if I may say, takes a neutral stance on many of the unresolved questions that we have to consider. In the early part of your paper—your introduction—the refrain seems to be that a great deal of research work is taking place in many areas, and that scientists are not yet agreed on many aspects of the problems. I wonder whether you would like to indicate to us the areas in which you feel in particular a great deal more research is required?

(Dr *Holdgate.*) I think your analysis of our position is correct. I believe that there are uncertainties in the UK which we are taking steps to fill as to the precise pattern of acid deposition in this country, and of the concentrations particularly of nitrogen oxides in the air over Britain. I think that there are uncertainties as to the proportionate contribution to observed effects—of the direct effects of dry deposition of sulphate and nitrate which means sulphur dioxide and nitrogen oxides' direct impacts on plants—and the direct impact also of other constituents of the atmosphere. In the German Forest situation, ozone is emerging as a factor of very major importance, as I understand it. The relationship between these and the wet deposited acids is also uncertain. The proportionate significance of the various atmospheric parameters and their deposition in rain, moreover, almost certainly varies from place to place and varies as between significance for forests, fresh waters and soils and indeed for buildings. I think that the major area of scientific uncertainty is the linkage of cause and effect between observed change and between emissions with the intermediate stages of transformation in the passage of various emitted substances through the air, in the rain, in the soil, in the fresh waters themselves.

161. What you are saying to us essentially is that our knowledge here is limited because fortunately, so far, within the British Isles, we have suffered little apparent damage, whereas in those countries that we have visited where there is a great deal of damage to be seen, there seems to be somewhat greater certainty as to cause and effect?

(Dr *Holdgate.*) Well, I am not sure that I intended my comments on uncertainty to be solely applicable to the UK. As scientists, certainly those of us who are concerned with this problem endeavour to keep up with the evidence as to scientific thinking in other countries, and some of us for example have been very much interested, myself included, in the situation affecting the German forests. I am aware that in those countries where there is complete conviction, severe damage is being sustained, and there is undoubtedly a very positive search for causes and some very confident statements have been made, but I think that our feeling about the situation is that while nobody disputes the

[Chairman *Contd.*]
reality of the changes observed, nonetheless even in many of those circumstances the chain linking cause and effect is less exact and rigorous than in an ideal world one would hope for.

162. Would you say this would be unfair? There seems to be greater uncertainty amongst those scientists who appear to be carrying out research for industrial concerns, the pollutant, if you like, than those who are carrying out research for other interests?

(Dr *Holdgate.*) I would I think say that I believe that there is a strong element of unfairness in the statement and say as a scientist that I would hope it always was unfair, because scientists (whoever they work for) ought to be objective.

163. I would not demur from that for one moment, but one forms impressions in the course of an inquiry, and I was merely articulating and I wished to have it cleared. Given that further research, in your view, is required, is it possible to give any indication of the reasonable timescale that one should expect that further research to take?

(Dr *Holdgate.*) It is extremely difficult, Chairman. So far as ascertaining the pattern, for example, of acid deposition, or getting better data on the composition of rain fall, which we know we need to do in the UK—filling in the gaps, for example, in the Report of the Acid Rain Review Group—that ought not to take unduly long, because it is a matter of going out and measuring environmental circumstances as they are, although to be cautious I would say that ideally, any measurement in something as variable as the environment, ought to span a long enough period to even out seasonal oscillations and to take account of the fact that circumstances vary from year to year. Research that is designed to quantify changes that are being experienced in lakes and rivers—some of it—can be done quite quickly. For example, the records of the sediments in the bed of lakes, the diatom skeletons preserved therein, do give one a historical record. You can take a core, you can analyse it, and you can have a historical record that spans decades, but which can be examined quickly. On the other hand, experimental research—for example, exposing plants to particular mixes of acid mist, and other pollutants, could well take longer. I am thinking here of about 2 or 3 years of research to get rigorous data on for example soils or natural water bodies. The Royal Society has, as you know, a 5 year co-operative programme in Scandinavia with the two Academies of Science there, and I would have thought that was a reasonable time scale for unravelling very complicated environmental situations. I wonder if Dr Everest would care to add to that?

(Dr *Everest.*) I think, changing a little from the actual research side, one of the points to note is the very large amount of research work which is being undertaken and published throughout the world on the acid rain problem. This in itself does bring major difficulties in interpretation and competent understanding. I think the Committee should be aware of a very large increase in the amount of published work, often of variable quality, which we do have to follow and understand.

164. One of the things that has been troubling us is that experience in countries abroad has been a series of warning signs over a period of years, of which not a great deal of notice has been taken, and then suddenly, and dramatically, episodes which have suddenly brought about the wholesale fish-kill in some lakes, or the sudden devastation of whole areas of the Black Forest in the time scale of two years, and what concerns us is are we in a position now within the British Isles where we are receiving the warning signals and we may ignore those at our peril?

(Dr *Holdgate.*) I think the only way of responding is clearly to look at what the warning signals have been in other places, while granting that one cannot simply extrapolate from, say, a Central Europe situation to a British Isles situation with our climatic and soil differences. So far as fresh waters are concerned, there are water authorities who have reported fish-kills. As I understand it, the North West Water Authority has reported fish-kills in the Cumbrian Esk and in the Duddon. That could be regarded as a warning sign. The Welsh Water Authority has been concerned with acidification in their rivers and has been carrying out some investigations accordingly. As far as the German Forest situation was concerned, I believe I am right in saying that tree ring data did show some diminuation in production and that the 1976 drought appeared to trigger more rapid change. The Forestry Commission has been looking at evidence of any minor damage

[Chairman *Contd.*]

or precursors in British forests, and their advice to us, although they will no doubt be appearing before you, Chairman, is that they have detected no sign of changes in British forests that are at all compatible with the changes that have been observed elsewhere.

165. Could you tell me, given that all this research is taking place, and discussions are taking place, between scientists as the results of monitoring that is undertaken become available, at what point in time it is decided to refer matters to Ministers for policy decisions?

(Dr *Holdgate.*) Well, Chairman, I will answer your question directly if I may: may I say something I should have said at the beginning, which is that we hope to send you a new table setting out the Department's research in this area in what I hope will be a slightly more helpful and simplified form than the two tables in our report. Turning to your point, Sir, the way in which the Department sets up and carries out its research really means Ministers are involved at the beginning when the programme is set up. What happens is that the various responsible under secretaries and assistant secretaries in the different parts of the Department have been charged with continuing responsibility for judging how far the information at their disposal is adequate to advise Ministers in the way they must. They bring forward proposals—generally on a yearly cycle, but on a shorter timescale if a problem will not wait—for research that will fill gaps. The proposed research programme is put forward to Ministers for approval, before it is actually put into operation. I, as Chief Scientist, have, as it were, a long-stop, additional responsibility, looking across the board of the Department's programme, to see that the various bits appear in reasonable balance and that gaps that appear to me, from *my* different perspective, are being looked at. The conduct of the research when it is going forward involves a continuing relationship between the nominated officers in the Department, in the customer directorates, and the contractors in the various research laboratories. It is not just handing the issue away to the laboratory and waiting until, in the fullness of time, a report lands on the desk. The dialogue alerts us to the research as it goes ahead: to any interesting and important findings, as they come in. This will be drawn on continually by the officials concerned, in advising Ministers. Obviously if something of particular import comes out of the research, we would let the Minister know at once, just as if any question comes out in the press or from another country, in the course of the research, the Minister is very likely to ask for technical advice which will in turn involve our consulting the researchers on whom we depend. So there is a very close two-way flow of information.

Chairman: Yes, Thank you very much, Dr Holdgate.

Mr Freeson

166. First, following on directly from what we have just heard in response to *your* question, Mr Chairman, could we be told at what point in time the Secretary of State for the Department, or another senior Minister below him, as it were, was advised by the research side of the Department and others that the issue which we loosely put under the heading of "Acid Rain"—though it goes wider than that, of course—was of particular significance policy-wise, or should be made of particular significance policy-wise, and should be pursued research-wise and policy-wise accordingly? When was this, is it possible to recall?

(Dr *Holdgate.*) I am not sure that there is a particular date. I would like any of my colleagues who remembers, to help. Maybe Mr Wilson would be able to amplify my remarks, to check the accuracy of my own memory. I believe that we began to be concerned first with this issue in 1972, at the time of the United Nations Conference on the Human Environment, at Stockholm, when the Swedish Government put forward a case study which claimed that damage was being done to their forests. At that time we were also aware of concern in Scandinavia for impacts on freshwaters. To that extent, awareness of these two issues dates back almost from the beginning of the Department of the Environment. More recently, there was certainly an investment by the Department in research with the Natural Environment Research Council, in Edinburgh, on the impact of acid deposition on a coniferous stand at Devilla Forest. This is Professor Last's work; it may be that this is well known to the Committee. At that period, I am not aware whether the Department was or was not funding research in freshwaters, and maybe my colleague can put this right for me.

[Mr Freeson *Contd.*]

167. When was this?

(Dr *Holdgate.*) This would have been around the mid-1970s, I think. It would have been about 1975. More recently, there was a period when the Department's research on what you broadly called "Acid Rain" was diminishing, but about two years ago Ministers took the decision that this must be reversed, and that we must consolidate and expand our research. We are now on an increasing trend the figures for which are contained in the table which I hope I may send you immediately following this meeting*. I wonder if I could turn to Mr Wilson who has been directly concerned with this, to amplify the detail.

(Mr *Wilson.*) In general, I think the figures that Dr Holdgate has given you *are* correct. Our involvement certainly started off within the OECD long-range transport exercise in the very early 1970s, and we have always had a very strong input, certainly on the atmospherics side, since that time. Again as Dr Holdgate said, we then realised that to tie in with this we should perhaps undertake work to see what impact this deposition of long-range transport might conceivably have. We did commence funding work on forests in the mid-1970s. Again, as to the exact date, it was either 1975 or 1976. We also, a little later than that time, funded some work at Nottingham University on the fumigation of field crops, to see what general effects air pollution had on crops. But certainly it is only within the last two years that we have really increased the programme to take on board other targets in the environment, such as the aquatic side and the effects on buildings and materials.

(Dr *Holdgate.*) If it would help, we could very willingly give you a little historical sketch covering the area of Mr Freeson's question, if you would like that.

168. I think that would be useful, because what is important to us is not just the facts that we are trying to elicit, but, if one may put it—and it is the way I think you were leading a few minutes ago, Chairman—the way in which decisions which lead to policy decisions are made or not made. Could I perhaps, before putting another question in the same field, try to fill in an important point of detail? Dr Holdgate started by referring to the Stockholm conference in 1972 when the Department was made very much aware, because of Swedish experience and other broader experience in this field. Can we be told what happened in the DOE on the research/policy side, following on that conference? Here we are told, rightly, that the Swedes and others have put forward a position—I will not put it any more strongly than that—which caused great awareness, concern and curiosity. What actually happened back in the Department after you were made aware as a result of that conference?

(Dr *Holdgate.*) One of the most important things that happened was, as Mr Wilson has said, the stimulus in OECD to do a study that tracked the pathways in the atmosphere, of emissions. Here we were particularly concerned at that time with sulphur dioxide emissions, to see how far we were involved in long-range transport to the Continent of Europe, and therefore to the acidifying deposition that might be affecting Scandinavian fisheries and, hypothetically, Swedish forests. I believe I am right in saying that the United Kingdom delegation played a central part in encouraging the Air Management Group (which is under the Environment Committee of OECD) to set up an international study of this long-range transport. This study was chaired for a long period by Dr Leslie Reed who at that time was a Senior Principal Scientific Officer in our Central Directorate on Environmental Pollution and is, of course, now the Chief Industrial Air Pollution Inspector. We undertook such things as aircraft-borne monitoring of sulphur dioxide pathways from the United Kingdom eastward on a westerly wind. We collaborated with other countries around Europe, and it was from this research that the critical analysis of transboundary movements, of back trajectories, of where an air mass had come from, were set in hand. I think that that was probably our major contribution at that time, really asking the question: Is it possible to state that British SO_2 emissions can come down in other countries? The answer was: Yes, it is. That came out of that work, with quantification. We moved on to effects, I think, at a somewhat later stage. However, I will endeavour, as I say, to see if we can put together an historical account for your help.

Chairman: Also, as a footnote to that, perhaps you could put in what decisions were taken at the time of the Control of Pollution act 1974 (because your studies will

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* Table printed in the Minutes of Evidence HC 446–x.

[Mr Freeson *Contd.*]

have then been embarked on for some two years), and what advice was then being given.

Mr Freeson

169. I make a second footnote, before I put my next question. There was an awareness of this issue back in 1965. That is when it first came to my attention as a politician, in general terms—and, I am sure, to many, many others' attention. It would be interesting to know what was going on in your predecessor's activities. I know that the DOE did not exist in 1965, but perhaps we could have a further footnote as to what was going on inside Government, after the point in time at which the Scandinavians first made reference to these matters to their own people and to others. Could I put one question which flows naturally from this? I get the impression—perhaps wrongly—that, as has been put to us, there is a tremendous amount of research activity going on, and in recent years it has built up not only in this country but elsewhere and is of a tremendous variety. However, would I be correct in saying (and I am not trying to put a leading question, I am just trying to express a feeling about it by way of a query) that there is a great deal of fragmentation in the research; that it does not seem to cohere, it does not seem to be being evaluated at any one important point inside either *our* Government machine (because there are other fields of research within the Department of Energy and within other Departments as well), let alone on a West European basis or a European basis? Is that a correct impression? Is there a need somewhere for some greater co-operation or central evaluation of the work that is going on? Does that require more resource or different kinds of organisation in Government?

(Dr *Holdgate.*) It is always possible to interpret results of research from different sources more effectively than one does, but I would not want to give the impression that there are not already quite considerable attempts to bring the results together. At the working level in this country there is, for example, a Committee on Air Pollution Effects Research, which brings together the Departments concerned, the Natural Environment Research Council and the universities. There is an interaction at a more senior level, between myself, as Chief Scientist DOE and also as the Deputy Secretary responsible in this field, with the Chairman of the Natural Environment Research Council—on which I sit, of course—and with colleagues in the Central Electricity Generating Board, with whom we have regular discussions, the Meteorological Office (to whom we look for a lot of information about climate and atmospheric movements), and also now with Sir John Mason, as the Director of the Royal Society's collaborative programme. Sir John Mason, Sir Hermann Bondi and I propose a series of meetings that will look at our three main blocks of the programme for the future. We rely on our professional research contractors—such as Dr Eggleton, for example—to keep in touch (and I know he does and he may wish to speak to this) with his expert colleagues doing analogous research in other countries. The other thing I would say is that increasingly, under the executive Body of the Geneva Convention on Long Range Transboundary Air Pollution, there *is* a pan-European international forum in which the results of research are to be exchanged, and which does provide a machinery for evaluations of their significance. Perhaps I might turn to my colleagues, because they may well wish to add to this. Dr Eggleton might wish to say something, as a contractor.

(Dr *Eggleton.*) We have been involved in a European Commission activity called COST 61A which is one of their concerted actions, and I think it started in 1972*, if my memory serves me correctly. We have represented the United Kingdom on that since that time. It is concerned with technical matters, with particular problems of atmospheric chemistry. Its first four years of activity were solely concerned with the behaviour of sulphur dioxide in the atmosphere. More recently, it has widened its scope to include a number of other pollutants. I can say as a contractor we have always enjoyed very close relationships with the Department of the Environment. We meet each other at frequent intervals and I have no complaints at all on that score. We are able to get our message across to the Department with no difficulty at all.

(Dr *Holdgate.*) It is only fair to say that there have been a number of major international symposia, two or three of them in the

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* COST (Coopération Scientifique et Technique) 61A was adopted by the Council of the European Commission on 15 March 1976 by discussions setting up the concerted action had taken place over the previous two years.

[Mr Freeson *Contd.*]

last year. For example, you may have seen this volume from the Royal Society's discussion meeting held last September. Also last September the European Communities, the Commission, convened a European conference on this subject at Karlsruhe which a number of us attended, so there is a large structure of interchange. There is, of course, no one "supremo" body, as it were, that pulls everything on everything together for everybody. That might not be the most effective way of co-ordination if there was.

Mr Chapman

170. Mr Chairman, you and Mr Freeson in a sense nicely anticipated the points I was going to put to our witnesses but it is really on this question of liaison between scientists of different countries on what is a very real and, if I may say so, expensive problem. We have been to the Black Forest and we are told that 50 per cent of the trees in their survey areas are now diseased to one extent or another. We have been to Norway and have seen rivers which no longer have fish in them, which must have an effect on their economy, and we are told in 18,000 out of 20,000 lakes in Sweden the fish are diseased or there are no fish, and the West Germans are embarking on a programme involving billions of marks. What I find incredible is that, given the scale of the problem, scientists in the appropriate countries have not come together to the degree that I think they should have done, but I am interested to hear of your paper. I did not know of the international study under the chairmanship of Dr Leslie Reed.

(Dr *Holdgate.*) That is the past.

171. Let me refer to page 76 of your evidence. You begin by saying that there has been public concern in Scandinavia since the 1960s, then you go on to explain about the conference in 1972 and the return conference in 1982. Let me also refer to page 23 of your very fair and most interesting evidence, where you say that this year you are spending £2.3m on research, to which has to be added the Meteorological Office's £0.7m and a few other figures like that. But the point I am making is that there seems to have been relative to the problem very little co-ordination on scientific research, on the one hand, and very little money spent on research, on the other, so I would be interested to have your paper of chronological events but I wonder if you would like to comment on that. I am sorry it is a long question and had to be prefaced but I think it is important. A lot of people are asking us why are we not doing more or appearing to be doing more to try and tackle this very real problem.

(Dr *Holdgate.*) May I try and answer Mr Chapman's question in three parts. First, I would suggest that there is a need obviously for scientific communication and exchange of findings between the working scientists but this will be on a within-discipline basis. It is not terribly helpful for, let us say, specialists in plant physiology who are examining the direct effects of ozone, nitrogen oxide and sulphur dioxide on the leaf tissues of plants to be very closely in communication with the fresh water biologists who are looking at what aluminium may be doing to the gills of fish, but it is essential that those plant physiologists are in touch with other plant physiologists anywhere in the world where the research is of relevance to their own studies, who will be helped by their foreign colleagues. I believe that kind of within-discipline, within-specialisms communication does go on among all competent researchers and it goes on through the very extensive international scientific grapevine, which is manifest partly through awareness of the literature, partly through professional conferences. The second level of co-ordination and co-operation is, of course, bringing together the multi-disciplinary programmes that are being done in different areas. This is something which at the scientific level is often done through major scientific symposia and meetings, such as the one reported in this Royal Society discussion volume, which was an attempt to look across the board with invited scientists who cover the multi-disciplinary components, and the Karlsruhe symposium attempted to do the same and there will be more. At the governmental level, which is concerned with looking at the interface between this science and the policy and looking also at whether the government should spend more money to amplify the science, I believe that the executive body of the Long Range Transboundary Air Pollution Convention, the Geneva Convention (which only had its first meeting last September and is due to have its next one this September) will prove to be a potent forum for putting together that kind of discussion, but I would understand the feeling that there is a question to be answered about the fact that the German government is

[Mr Chapman *Contd.*]

investing many billions of Deutschmarks in their research. In the United States the Environment Protection Agency has a very large programme indeed of research in this area, I think of the order of $50–70m, subject to correction by my colleagues. That is a figure plucked out of my memory. We have a modest programme which is probably not far short of £5m a year if you take the main components of it, and we are all conscious of the need to design our programme in awareness of what is going on elsewhere. I would certainly hope increasingly to be informed about programmes in other countries and to be satisfied that our scientists and their scientists are in good communication. It might be a good test to ask Dr Eggleton, as a contractor, if he feels that in his particular specialism the international work does co-ordinate effectively.

(Dr *Eggleton.*) I think it is co-ordinated very well. In fact, one can almost say there are too many meetings on this topic. We do not have any time actually to do the work. That is an exaggeration, of course.

(Dr *Everest.*) I think the Committee should take into account the very large scientific size of the problem which we are facing and the very large advances which have already been made. First of all, to start from the beginning, you have to understand emissions, obtain emission data. You have then to understand the chemical processes that take place in the atmosphere when these pollutants move. We have made a lot of advances in this field. The work is new; a lot of new material has come out and we have to understand and digest it. Meteorological factors come into play; we have to understand the meteorology of the whole system. We then have to look at the various effects which are causing the problems internationally. First of all, we have acidification of the environment, which shows up in the fishery problem. That comes from a lot of sources. It comes from natural processes, it can come from agricultural practices, from acid deposition. How do we sort one set of problems out from another? We have made a lot of advances and we are beginning to understand internationally what causes fish kills but it is not a simple problem. We have started developing a very elegant method, diatom counting, to identify problems that have a historical association with acidification processes. This allows for the fact that conventional measurements of acidity are actually more difficult to make than would appear to be the case. Moving into the forestry area, only recently have surveys started on the forestry problem on the Continent and it has still not been observed in this country, so it is a Continental problem. It is not at all clear what precisely causes it, although there is increasing evidence that it is ozone. Then you have to consider the formation of ozone and how that fits into the overall picture. We have made a lot of advances but we are not going to get a very ready consensus on such a large and complex set of problems, especially when there are considerable variations internationally regarding the concerns, which puts increasing effort and emphasis in different places.

Chairman

172. I wanted to move from consideration of general questions on research onto the more detailed aspects but in view of what has been said can I put this last question on this part of the discussion. As scientists you are looking always for 100 per cent certainty before reaching a conclusion. I think that must be so, or as near 100 per cent as is possible. In so far as political decisions have to be taken, to what extent should politicians await complete certainty before they take action?

(Dr *Holdgate.*) Chairman, I smiled and shook my head because when I was a practising scientist I was an ecologist and in so complex and multi-disciplinary an area as the natural environment certainty is a luxury we can very rarely enjoy. It may be more common with our mathematical and physical sciences. We would say that science proceeds on the basis of the best hypotheses that can be formulated at the time and which stand up reasonably well to the full consultational checking and the best we can hope for is the conviction that we have a balance of probabilities that strongly points in a particular direction. As to the political and policy side, I have to put on a different hat here, of course, as the senior civil servant in the Department of the Environment concerned with this area of pollution. I think that one is acutely conscious here of the fact that the judgment has to be made on the best balance of probability at the time, but also bearing in mind the implications for the community of getting it wrong. In a sense—I am putting it very crudely—if the evidence shows it is highly plausible that there is a major risk to the health of millions of people, then you give very high priority indeed both to evaluating as quickly as

[Chairman *Contd.*]

possible the evidence and to precautionary action, because it is prudent. If, equally, the best scientific evidence implies that there could be a significant economic cost, that attaches high priority to coming to the best judgment, but if, equally, action to correct a problem involves a massive commitment of the community's resources where getting it wrong can be an extremely expensive business, you would be looking for a substantially strong case before you committed those resources, especially bearing in mind that if you do get it wrong in a very expensive way the community may not be eager to give, as it were, another hypothetical try. I am answering this in very general terms. I think that is almost inevitable. All one can do is say that one has to balance the probabilities of a problem, the probabilities of damage, against the implications it has for the community of inaction versus action and probably in any one decision this balancing act goes through successive stages.

Mr Jones

173. Following on that particular answer, do you feel having a reasonable understanding of the mechanisms that are occurring is essential, because the comparison that has been put to us has been cigarettes and lung cancer, where still there is remarkably little agreement about the mechanism by which one affects the other but the balance of probabilities is still sufficiently strong for political action to have been taken? We know quite a lot in the case of acid rain about the effects. We know quite a lot about the toxicity of emissions, but to what extent are we now, therefore, dependent on understanding the mechanisms that link the two?

(Dr *Holdgate.*) With respect, I would not draw quite so close an analogy. The cigarette smoking/health story was one where highly significant statistical correlations were drawn between certain medical effects and a particular single factor which could be related by statistical process without the causal chain being analysed in any detail. I would suggest to the Committee that in this particular area we are dealing with the effects cannot be correlated statistically anywhere near so simply with particular causes. If, for example, you take the German forest damage situation, when it first came to light a number of people advanced the hypothesis that it was related particularly to sulphur dioxide pollution. If you actually look at the pattern of damage along the frontier between the Federal Republic of Germany and Czechoslovakia, at one end of the frontier there is acute damage, particularly at higher altitudes in areas where the measurement of sulphur dioxide in the air is also high, but at the other end of that frontier in the Bavarian National Park I think you will find the concentrations of sulphur dioxide are relatively low and the lichens that grow on the trees that are often an indicator are also profuse. But, on the other hand, there is some evidence that may correlate with ozone levels. Similarly, there are arguments that in some parts of the Federal Republic there is a relationship between this damage pattern and high levels of aluminium in soils related in turn to high deposition of acidity to the soil; but patterns of damage in the forest do not correlate very closely with particular soil types. Now, Chairman, I am not discounting any of those as factors; what I am saying is, if you look into this particular situation, you have the combinations of at least three kinds of air pollutants—sulphur dioxide, nitrogen oxides and ozone, the latter a derivative from chemical reactions involving hydrocarbons and nitrogen oxides in the presence of sunlight. You have the hypothesis that wet deposition of acidity can play a significant part also in the mechanism, dissolving essential ions from the leaves that may already have been damaged by air pollutants and stressed by droughts or extreme low temperatures; so drought and low temperatures come in. You have a much more multi-factoral situation. I think the danger is that there is not a simple statistical correlation with a particular variable. That is why I discounted the smoking and health analogy.

174. Are you saying that applies as much to the loss of fish as to forest damage where obviously there are other factors involved, including particularly the buffering effects of soils, or do you think there is a stronger correlation there than in forests where you have far more different factors?

(Dr *Holdgate.*) I think that the relationship between fishlessness and low levels of calcium alongside high acidity, and perhaps increased aluminium in many of these deprived waters, is, as I understand it, a good one, but I think tracing back the particular chemical story that gives rise to those changes in the fresh water is still not simple. One has a broad correlation undoubtedly with acidity of run-off which in turn one

[Mr Jones *Contd.*]

can plausibly deduce back to an impact—a plausible impact—of deposited acidity from the air modified, as you have said, by changes in percolation through the soil, perhaps also affected by the interplay with land use factors in catchments. What I am saying is that I do not think that the causal chain, or the simple correlation with single factors, is anywhere near as clear in this area. This is, of course, our difficulty.

Mr Jones: I would want to pursue this, Chairman, when we come to emissions and deposits.

Mr Taylor

175. My question is on the general chapter. If I could share one problem with Dr Holdgate, he has been very scrupulous and most helpful in the way that he has guided us on these questions of the best balance of probabilities. I did notice that in a much earlier comment, when referring to the speculation that existed some time ago as to whether these pollutants were capable of long distance carriage, he permitted himself to say he felt the case for the fact that they could be was more or less made out, so there at least was an area of certainty. Whilst I am not a scientist, only a layman, it does seem to me that in the unestablished areas the scientific orthodoxy is very often to apply common sense and special skill to try and arrive at what seems to be the best intuitive solutions and then very able minds try to work backwards and prove them and see if those intuitive solutions meet the facts and are performing as is thought. The orthodox view at the moment, Mr Chairman, is that the damage is somewhere shared between oxides of nitrogen, sulphur dioxide and ozone and photochemical processes; somewhere within that umbrella of pollutants is to be found the villain of the peace. I gather Dr Holdgate is a scientist. The only thing that worries me slightly is that occasionally scientific research men looking for one thing surprise themselves and find something else. Is your reaction as a scientist looking at nitrogen oxides, sulphur dioxide and ozone, that we are in for a surprise or is the solution in your view somewhere there?

(Dr *Holdgate.*) Mr Chairman, may I just pick up the first point Mr Taylor made and say I do stand by what I said: I believe we were able by airborne monitoring and atmospheric measurements to ascertain beyond peradventure that there was transfrontier movement of sulphur dioxide. That is a much easier thing to measure, you can trace a plume with an aircraft. On the envelope of SO_2, NO_x and ozone, I would be bound to say, I think, that these are significant factors but I would not necessarily believe that within those three factors was the whole answer either to the forest damage problem or to the acidification of fresh water problem. I would say that, so far as forests are concerned in a sense we have surprised ourselves in that the original simple hypothesis tended to concentrate on sulphur dioxide creating deposited acid. As the scientists have investigated this matter the relative significance of ozone as a factor has come more and more out of the investigations, and I am impressed by a study Professor Rutter and his colleagues at Imperial College have done for us which implies not proof but that in the Federal Republic of Germany, where measurements have been conducted, ozone concentrations are in the range that in the laboratory might be expected to damage sensitive plants. That is a quite different statement from the old hypothesis that the sulphuric acid comes down, needles go yellow and away goes the plant. I would likewise say I think within the envelope one has to consider the nature of soils, one has to consider climatic factors. There is evidence that the sensitivity of trees to air pollutants is increased by the stress of extreme low temperatures in winter and probably by the stress of drought in summer. Similarly in the fresh water situation I would hypothesise that you can forget ozone, that deposited acidity will only plausibly make sense in the story if you take into account the interaction of that acidity with the soil and rock because, after all, 90 per cent plus of the rain that comes down does not go direct into the water body, it goes into the catchment where there are complex chemical reactions; and there is some evidence that in acid soils the percolating drainage water is enriched in aluminium which one knows to be a factor that correlates with fishlessness in the waters themselves. Of course, the water chemistry reacting with the deposited substances is of crucial importance. So I would say that, while in the fresh water situation sulphur dioxide and nitrogen oxide are within my envelope of factors, I would look to what they interact with as being of crucial importance in this story. It is in that area that I know the Royal Society is helping to

[Mr Jones *Contd.*]
support research with the Scandinavian academies.

Chairman

176. Could we move on from there and come to Part II of your paper, the part dealing with emissions. We have been discussing just now the greater significance that nitrogen oxide and its conversion into ozone is now having in scientific thinking with regard to forest damage. In your paper you indicated, I think in paragraph 6, that there is a scarcity of data available as to emissions of nitrogen oxide. Can you tell me what research is being undertaken and what kind of a network we have for monitoring nitrogen oxide in the atmosphere in the British Isles?

(Dr *Holdgate.*) Yes, Mr Chairman, with pleasure. There are three stations in Britian* at the moment that are monitoring nitrogen oxides, namely, the station at Vauxhall Bridge Road, the station at Warren Spring Laboratory and the station at a place called Sibton which I understand is in Suffolk, certainly in East Anglia. In addition there are some measurements at Harwell of secondary air pollutants, that is, the derivatives including ozone†. It is common ground between us that we have to do more. We need this for our own understanding of the science of the situation. It has been urged by the Royal Commission on Environmental Pollution. We would in any event be obliged to expand our monitoring network under European Community directives on air quality. Lastly, but by no means least, the Long Range Trans-Boundary Air Pollution Convention's executive body has called for more attention to nitrogen oxide monitoring. We therefore plan to expand our national network with ten high quality stations as we call them (and Dr Eggleton can expand on this) and a secondary network that might involve up to 50 sites. We believe that this will give us a much clearer idea of the pattern of nitrogen oxide distribution and, indeed, of depositions over this country. It is not cheap.

177. You say you are planning these extra stations. What is the timescale?

(Dr *Holdgate.*) I hope it will be operational, or beginning to be, in a year or so. Mr Wilson is negotiating the contract.

(Mr *Wilson.*) Yes, indeed, Mr Chairman. Steps are at present being taken in discussions with the working group of the Acid Deposition Review Group. They have set up a small working group to advise us on their recommendations and we are also looking at the Royal Commission's Tenth Report which also has recommendations relating to the oxides of nitrogen and ozone. We are certainly hoping to get some of the work started in this present year but I think in terms of the oxides of nitrogen and ozone the bulk of the siting and instrumentation will be carried out next year, 1985–86, because it is a very complex procedure to set up a new site in terms of negotiating the site itself, getting instrumentation, calibration and suchlike. So I think we will be looking for the bulk of the nitrogen oxide measurement and sites and ozone measurement sites to be set up next year, 1985–86.

(Dr *Holdgate.*) We want to get the statistical design right. The group advising us is the one behind the authorship of that red report.

Mr Freeson

178. So when this programme has been established within the next 18 months or so, hopefully will you be satisfied that you have the national coverage that is required?

(Dr *Holdgate.*) Yes, I think so, in so far as present knowledge provides a guide to the design of what we need. We would obviously see what comes out of the network and how satisfactory it is as a basis for answering the questions we would then pose.

179. With all these many contacts with other people in Europe, how will this package relate to a similar network elsewhere in Western Europe? Is there a general pattern of work even in this one respect which is being co-ordinated—and I use the word with its literal meaning, not consultation and contact but co-ordination—on at least a Western European basis?

(Dr *Holdgate.*) Mr Chairman, last year in the first meeting of the executive body of the Geneva Convention we urged other countries to take nitrogen oxides more seriously. We shall inform them of what we are doing at the next executive body. I believe Mr Burgess may wish to come in

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* *Note by witness*: This Figure excludes 2 stations operated by the GLC in London.

† *Note by witness*: Nitrogen oxides have been measured at Harwell since October 1983.

[Mr Freeson *Contd.*]

here. That will be a co-ordination in the sense of the national programmes being set alongside one another and looked at as a whole to see how they add up satisfactorily to the European picture.

(Mr *Burgess.*) Among Community countries we only know of three which actually have monitoring networks: the Federal Republic, France and the Netherlands. They do this for their own purposes, in each case for rather different reasons. Assuming we do have a directive on nitrogen dioxide, that is air quality standards for nitrogen dioxide, that will bring together to some extent the work being done in the Community on the subject, although this will be worst-case monitoring which is rather different to that to which you are referring. But the work under the European Monitoring and Evaluation Programme, which is part of the convention, is to some extent conditioned by the speed at which the Member Countries will go. Not all countries are so keen to get on to nitrogen oxides; particularly Eastern European countries are not so keen. So to some extent that work will be conditioned by the willingness of all the parties to the convention actually to get on with that work.

Mr Jones

180. On the subject of emissions, but switching from Nitrogen Oxides to Sulphur Dioxide, you base your comparison on table 4. There are 30 countries in table 4, very approximately, and yet the 1950 base is only the emissions for six countries. Is that really statistically valid to compare therefore 1950 with up to date? Particularly, I would suggest, since those six countries appear to be very much estimated figures in any case, and they do not include any from the socialist bloc who we are told are responsible for something like 60 per cent of European air pollution, so what is the statistical validity of Table IV?

(Dr *Holdgate.*) By curious coincidence I asked this question of my colleagues this morning, and we went over this. The figures in the Table are, I am told, official figures from governments returned to the European Monitoring Evaluation Programme, which is thus data support for the Geneva Convention, but the paper in section 2, paragraph 5, with the 1950 statement, for example, is based on our own departmental re-calculation from fuel usage statistics alongside data on the sulphur content of the fuels used and it has been done by a colleague on our staff. Similar calculations have also been done within OECD and I believe by Swedish specialists, so there are as it were different data in the text and in the table. Our statement in the paragraph to which you refer is a general statement that "It is *believed* that emissions in Europe have doubled since 1950 while emissions in the UK are currently below the 1950 level. It is *thought* that in 1950..."—and the "belief" and the "thought" derives from the fact that these are calculations by us done in the fashion that I have described, whereas the table is, as I say, official government returns to EMEP.

181. Does that not strike you as being rather a dubious base on which to put forward the seemingly complacent view that we have actually done quite well in the UK compared with Europe generally?

(Dr *Holdgate.*) No, I do not think so. It is the best calculation that can be done. The methodology that we have used was not worked out in the UK. I think I am right in saying it was the Swedish technique which we have applied and I believe that it is also a technique which is being established as a working method by its use in OECD, so there is nothing we have done that is a peculiarly complacent British analysis of this problem. It is simply using the best technique that has been worked out to calculate from fuel statistics what the probability of emissions was.

Chairman

182. It still leaves us pretty near the top of the league, though, does it not, if not at the top of the league of emitters?

(Dr *Holdgate.*) Yes; in terms of emissions this year, or last year, for which we have figures, the UK does come out as probably the largest emitter in Europe. I hesitate to say this and do it with all diffidence but if you do actually re-calculate the figures I have heard it stated that the Federal Republic of Germany actually comes out on some basis of calculation as emitting more than us and more than their own official figures while Italy comes out as emitting a good deal less than its published figures but I think we are wisest to rely on the official estimates which leave us at the top of the league.

Mr Jones

183. Following on from that, moving on to your section III, paragraph 5, that is where you talk about us exporting 30 per cent of our emissions which is less than 6 other countries, and you have established in the last answer that in fact we are near the top of the league if not absolutely at the top. Supposing one takes the assumption that those countries which have joined the so-called 30 per cent, actually achieve their 30 per cent reduction and West Germany, which you said was our rival at the top of the league, actually achieves its reduction of substantially more than 30 per cent. Where would that then leave the UK in terms of its contribution to the pollution total?

(Dr *Holdgate.)* I think with respect I would want to do the sum before I gave a precise answer. The hypothetical answer to the question must of course depend on what our own trend is bearing in mind that we have experienced a progressive reduction in our national SO_2 emissions since our peak of 1972. I would honestly not want to guesstimate the answer but it may be that some of my colleagues who go more deeply into these statistics would like a chance to answer.

Chairman

184. Before we go any further, we seem to have leapfrogged from emissions to depositions. I want to make it clear that we are doing that but I believe Mr Alton wanted to ask a further question on emissions before we get onto depositions, so we are still on part 2 of the answer.

(Dr *Holdgate.)* May I just say that what, from behind me, has just been commented is that of the 6 countries who contribute more to other countries than we do, only the FRG has in fact committed itself to joining the 30 per cent club.

Mr Alton

185. First of all, can I draw your attention to Table 5, and ask you some questions on the Nitrogen emissions. I wonder why it is that so much information was available in 1978 compared with 1982, which were the last available figures which were given? Also, given the sparseness of the information actually available, the last available figures showed, if I read this proposal in 1982, only two countries—France and ourselves—as listed. On that basis, I wonder really what use this kind of evidence really is, and what is being done to try and provide better estimates than that? The other point is this: in terms of our own emissions, what research have you done into the differences between the NO_x emitted as a result of vehicular emissions as opposed to those of power stations? One final point, I appreciate that in sections VI and VII you actually deal with emission control options, and I do not think it is the Committee's intention particularly to pursue those matters, but is the technology being developed in this country to deal with NO_x emissions or is it a case of the only place that has got any technology capable of tackling NO_x being Japan?

(Dr *Holdgate.)* Thank you. On Mr Alton's question, first I entirely agree with him (I think all my colleagues would too) that this table does indicate very strongly why it is important to improve our study of Nitrogen Oxide emissions over Europe. The table is indeed a pretty inadequate one. Second, I think we would say that the United Kingdom figures which we believe bear comparison with anybody else's nonetheless are not arrived at by as rigorous a process of judgment as we would wish, and we would hope to improve their base. A third point: I think you asked whether we were examining the distribution of the different sources of Nitrogen Oxide. There is in the Department's published Digest of Environmental Protection and Water Statistics a breakdown in the relevant table of the sources of Nitrogen Oxide and Carbon Monoxide and hydrocarbons. Again, this is a calculated figure, as I understand it, related for example to statistics of fuel usage but it does show that for example 46 per cent in 1982 was attributed to power stations; 19 per cent to petrol engine road vehicles and so forth. We would dearly like to improve the rigour of that kind of analysis which is clearly important when it comes to considering the balance of possible controls. On Mr Alton's last point, indeed, technology for dealing with Nitrogen Oxide emissions is to our knowledge being researched. The CEGB is supporting quite considerable research about which they will, no doubt, be glad to give evidence to you, for low NO_x burners suitable for adoption both in the wall-fired and the corner-type fired power station. I understand, but clearly they are the authority, that the research shows promise, but it is too early to see whether it is a cost-effective method

[Mr Alton *Contd.*]

for introduction. Somewhat similar research is going on in this country and elsewhere on the design of the motor vehicles, particularly petrol engine motor vehicle engines, applying the so-called lean-burn technology, which correctly tuned could bring down significantly the total NO_x reductions. Those are two areas of work in this country.

186. If I could go back to the first of the questions I asked, just to pursue that with you further, I did ask you why there was such full information for 1978 compared with the last column (1982), and whether those figures are to be relied on, given that, for instance, the Federal Republic is shown as having twice the rate of emissions in 1978 that we had in 1982, and also given that in that year we are shown as having a larger emission of NO_x than in 1982. Given that the numbers of cars owned by the population have increased during that time, can those figures really be relied on at all?

(Dr *Holdgate.*) Perhaps I may ask Mr Burgess to explain the completeness of the 1978 column.

(Mr *Burgess.*) The 1978 column is the result of a survey done by the ECE in Geneva, I understand, so that some national figures were obtained for that year. Most countries, as far as we know, do not produce statistics. France does, and we have those statistics. That accounts for the fact that we have France and the United Kingdom alone there. As to the extent of the Federal Republic's statistics, I am afraid I cannot give you an answer to that. Car ownership obviously is higher in the Federal Republic, and that may have some bearing on it. We feel that our figures probably give a reasonable idea as to trend. What we are not confident about is that they give reasonably proper emission figures, because we have to do these by application to use, and we only assume that other people do use the same method.

(Dr *Holdgate.*) I have seen the figures attributed to Germany in German publications. For example, I have a reference to a paper on forestry effects in West Germany, by a Dr Krause, which was presented to a Washington symposium last October, which quotes the same figures of a rise of 50 per cent in total emissions in Germany in what he calls "the past 15 years", from 2.05 to 3.0 million tonnes. That is the same as in this table, between 1966 and 1978 in that case, and would suggest that these figures are at least accepted by some German scientists in their publications. As to the reason for the difference to which Mr Alton alluded, I understand—but I think that really this is a guesstimate—that perhaps it is as a result of the substantial increase in motor vehicle density in the Federal Republic. At the same time, it implies that we have been more successful in this country, for one reason or another, in holding down our nitrogen dioxide emissions, than they have. I do not know the cause of that. It may be that my colleagues would care to comment.

(Mr *Wilson.*) I was in Paris last week, talking to a German delegation about this, and they do accept that they seem to have had a 50 per cent increase in their NO_x emissions, which they put down to motor vehicles—both an increase in the number of motor vehicles and in engine size, and the way they drive. What is also significant, I think, is that they too are seeing an increase in the emissions of hydrocarbons from their motor vehicles. When perhaps we come to talk about effects on forests, this could be quite a significant factor.

Chairman: Yes, we did hear something of this ourselves, when we were in the Federal Republic. Now we will move on, if we may, to deposition.

Mr Jones

187. I thought there was a supplementary answer to my question. I had gone on to deposition earlier on, in reference to the projected totals of the United Kingdom compared with the 30 per cent club and so on. Dr Holdgate did say that he would like to give a supplementary answer when we came back to this topic.

(Dr *Holdgate.*) I did slip it in when I said that of the six countries named as being worse than us, only one had signed up for the club.

188. The point I wanted to make in reply to that was that we all accept that there is a problem with the Socialist Bloc, but that is not in any way to undermine the argument within the OECD countries.

(Dr *Holdgate.*) I would accept that point. We will look to see if it is possible to do this sort of calculation. I am not optimistic. I think that the assumptions one would have to make would be quite sweeping.

Mr Chapman

189. I would like to pursue Mr Jones's point, referring to paragraph 5 of Part III of your paper. I say this with the greatest respect. I will not say that what you suggest is misleading, but it does give the impression that we have got a favourable record compared with most other countries. However, it seems to me that the evidence that has been presented to us suggests anything but that. When we were over in West Germany—and I am referring to sulphur emissions, as the paragraph does—we were told that Germany exports 50 per cent of its sulphur emissions, and 50 per cent of its pollution is imported, one for one. You are trying to suggest that we export only 37 per cent of our sulphur emissions, and that 38 per cent fall in the United Kingdom. Of course, 25 per cent—using your figures—presumably fall in the sea?

(Dr *Holdgate)* That is right.

Mr Chapman: If Germany were surrounded by sea it would not be exporting 50 per cent of its sulphur emissions. It may be by an accident of geography that we are in a more favourable position, but to try to pretend that we have a better record *is*, I think, pushing geographical considerations too far. You know that politicians can manipulate statistics in any way they want, but it seems to me that you are trying to suggest that paragraph 5 of Part III of your paper shows us in a very favourable light, when I would like to suggest—I hope it is not true, but I would like to suggest it—that it does anything but that.

Mr Freeson: Before that is commented upon, could I say that the answer should also take account of the fact that we should not always be talking in percentage terms, but in actual figure terms.

Mr Chapman

190. Absolutely. What is your comment on that?

(Dr *Holdgate.)* Far be it from me to impute any particular vices to politicians, but on the serious point, of course Mr Chapman is quite right: the figure here is for the percentage of our emissions that arrives over the territory of other countries, and we have the good fortune that a good deal comes down in the sea. The early OECD studies suggested that 50 per cent of our emissions could leave the country on a westerly wind. Indeed, this figure might imply that more than 50 per cent goes over; that 62 per cent leaves Britain, but, happily, only 38 per cent reaches somewhere else. It can be argued that this is an environmental blessing from which the United Kingdom is benefiting or at least the other countries are benefiting, but I will leave that there. On totals, I think I am right in saying that the actual tonnages, as well as the percentages, are available in Table 1 in this section. I am also told, incidentally, that the Italian figure is in error, and we are going to send you a correction. These figures are in hundreds of tonnes per month. It is sulphur, not SO_2, but it does show figures as well as percentages (taking Mr Freeson's point). Our evidence is not intended to do more than be factual. Paragraph 5 was intended on that basis. I think I am also right in saying that the latest OECD analysis or certainly international analysis implies that 7 per cent of the sulphur dioxide deposited in Germany has its origin in the United Kingdom. That is a statistic which I believe we can substantiate, to set alongside the statements that you may have heard in the Federal Republic. I think it is also a fact that our total emissions have come down very substantially, by some 34 per cent since 1972, as a result of changes in our energy situation, energy conservation, fuel mix and a host of other things.

Mr Freeson

191. I am not sure whether it was a failure on my part to listen closely enough to all that, but I am still not clear as to whether the actual quantity of our exported emissions exceeds the six countries which, on a percentage basis, we are lower than?

(Dr *Holdgate.)* The table to which I was alluding does show that our total export to other countries is 64,100—let us say, 641 of these units—per month. We are exceeded, therefore, in this table, by Czechoslovakia, the German Democratic Republic, the Federal Republic of Germany, Italy—but I am told it is in error—Poland and Yugoslavia. Those are total figures.

Chairman

192. But two West European countries?

(Dr *Holdgate.)* Yes. I do not know if Italy exceeds us.

193. It may only be one?

(Dr *Holdgate.)* It may be the only one of the EEC countries.

Mr Freeson

194. At this stage in history my question may not be very important but much has been made of the fact that we lose 50 per cent of our exports over the North Sea. Has any research been done yet as to the effect on the sea?

(Dr *Holdgate.*) No, Mr Chairman, but I think back of the envelope calculations would suggest it would be negligible because the neutralising capacity of a concentrated solution like the sea—and the sea is a relatively concentrated solution—must be immense in relation to the inputs.

Mr Jones

195. On the question before last, have we now established, therefore, that outside the Communist bloc there is one country, West Germany, which has greater tonnage exports than ourselves and that actually is the country which has the toughest programme in line to deal with that and is that not the kernel of it?

(Dr *Holdgate.*) I think that is correct. I do not know that any of my colleagues would dissent. No, we are all agreed.

196. Could I go on to section III.3, which is about switching off power stations if pollution episodes could be predicted. Is it not the case that it is not the emission of the pollutant anyway which is critical but the release of that into fresh water and that in a snowbound climate where you have a snow-melt where a great wave of water comes down at once that is actually much more critical and switching off power stations would have no effect on that particular problem?

(Dr *Holdgate.*) Mr Chairman, the statement that is made is made in pretty hedged and hypothetical terms. If an episode could be predicted its magnitude might be reduced. This statement as a whole depends on an analysis done by Dr Philip Goldsmith of the Meterological Office with his colleagues, F B Smith and A F Tuck, which is found in The Royal Society's volume. He himself did put this forward as a possibility at the Royal Society's meeting and it is in page 276 of the document in question. He says: "Another possibility, with appeal to the meteorologist, is based on our earlier discussion of the importance of episodes. If trajectories of plumes can be forecast with sufficient reliability... then it could be argued that a very cost-effective way of reducing the depositions would be for major emitters to change over to low sulphur fuel when such 'alerts' were forecast." He goes on to say: "An early study in 1974 of the feasibility of doing this for sources in the UK Midlands and a receptor area in Southern Norway suggested that only about a 45 per cent success rate could be achieved. However forecasting models have improved since then" and the Meteorological Office with their new computer intend to repeat the study. I have to reply on Dr Goldsmith's authority but that is where that statement came from and you might wish to explore that further with him.

197. Have you any comment on the point I was making about the snow-melt episode?

(Dr *Holdgate.*) It is, of course, absolutely correct that episodes in fresh waters, for example, in Scandinavia do result from, among other things, the sudden melt of accumulated snow, just as they may also result at other times of the year, such as autumn, from the sudden flushing-out of acidity from soil when a long, dry summer is succeeded by periods of heavy rain. I put that question to Dr Goldsmith myself but his belief was that despite the evening-out, as it were, or the accumulating effect of snow, nonetheless reducing the episodes of deposition must reduce the accumulation in the snow, so that even with the snow-melt less total acidity would come in.

Mr Freeson

198. Would that tackle the "alert" question?

(Dr *Holdgate.*) Your alert would depend on forecasts from the Meteorological Office's computer of when a pulse of British sulphur would zoom down a trajectory, as it were, and deposit in Scandinavia. We know that a high proportion of the acidity is deposited on a small number of rain days. If, therefore, the Meteorological Office forecasts are predisposed to the long-range transport, you will not deposit, so you will not accumulate in snow. That would be the argument, but, as I say, this is not primarily my authority or our departmental authority. We were quoting this particular reference, and I think that the atmospheric transport machinery and its relation to climate is so much in the Meteorological Office's sphere of expertise that I would, with respect, like to defer to them and suggest that if the

[Mr Freeson *Contd.*]
Committee wanted to pursue this it might be more appropriate to speak to them.

Mr Alton

199. Since we have changed to a policy of having high stacks, what monitoring has been done in the rural areas of the levels of sulphur deposition that have occurred since that change in policy took place?

(Dr *Holdgate.*) I was almost ready to answer Mr Alton's question until the last phrasing. We had some 38 sites in rural areas in the 1978–80 period and they are being extended by the Warren Spring Laboratory to fill in the obvious blanks on the map which are in their red paper. To that extent, with the assistance of the Acid Rain Review Group, who are helping us plan this network, we are proposing to satisfy ourselves we have an adequate network of rural sites, but, Mr Chairman, the tall stack policy in Britain has been a phenomenon for a very long period and we cannot do anything to give ourselves rural base lines that antedate that policy, so I do not believe anything we have now would be able to give us a critical scientific analysis of Mr Alton's particular question*.

Chairman

200. We have still a lot of ground to cover. Perhaps we could write to you if there are any figures that we need on matters of deposition. I would like to move to section IV, the effects. We are, of course, very concerned with the United Kingdom position and you have said at the end of paragraph 7, after you have dealt with the effect of ozone concentrations in the Federal Republic: "In this regard it is important to confirm the recent reports of forest damage in the UK similar to that in the FRG." Would you like to elaborate on that?

(Dr *Holdgate.*) I think I can do it in two words—false alarm, or so we are told by the Forestry Commission. At the time we put in this memorandum to you we had seen such reports but I am told—and we look to the Forestry Commission as our specialist advisers on forest damage—that they are not similar and they do not believe there is any evidence that is available to them of damage in the United Kingdom analogous to that in the Federal Republic.

201. Thank you, that is reassuring. How about other plants, other vegetable life? Is there any evidence there at all?

(Dr *Holdgate.*) The Ministry of Agriculture, Fisheries and Food believe that there is no evidence of significant or detectable effects on crop growth in this country. We have been funding quite a lot of research in the past on possible effects of air pollutants on plants and there is no question that some of these air pollutants can be shown in the laboratory to reduce the growth of sensitive species. It is extremely difficult to separate the various gases that may be involved in this process: Ozone, the direct effects of NO_x and of sulphur dioxide, which can, incidentally, potentiate one another's effects in the laboratory, or the acid deposition in rain. We can show in the laboratory that ozone can check plant growth at near the sorts of concentrations which we know occur in the environment. I think the problem is that one can hypothesise there is a possibility of marginal checks to plant growth, to crop growth, especially of sensitive strains in this country, but it would be hard to distinguish these in the field from the various dominant factors which affect the production of crops at any time, such as a dry spell, such as a bit of blight, such as sub-optimal cultivation. The dominant influence on crop growth is the way the farmer cultivates his land and I suspect variations due to these factors would tend to swamp the very small variations in pollution and make the latter extremely difficult to detect. The best hope is in the use of what are called open-top chambers and certain other kinds of field experiment that try to vary a single pollutant in the field to see how far the crops respond. But that work, I believe, has not given us grounds to believe that we are likely to have a significant problem in the United Kingdom either. This is something about which you may wish to ask the Ministry of Agriculture, Fisheries and Food, of course, as we rely on them for the agricultural evaluations.

202. In connection with that answer, is there anything you would like to add to your paragraph 11 where you talk about the acidification effects on the western part of the United Kingdom?

(Dr *Holdgate.*) I do not think so, Mr Chairman. I think that is a fair statement. It is a matter of knowledge to any ecologist.

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* *Note by witness*: There is a considerable number of research papers published by Staff of the CEGB dealing with concentrations of SO_2 measured round power stations, both with and without tall stacks.

[Chairman *Contd.*]

203. Could I put it more particularly—has damage been observed?

(Dr *Holdgate.*) No, I am not aware that damage has been observed. If you look, for example, at a paper in this Royal Society volume, by a botanist called Clymo, he points out that on an acid sphagnum bog because of the natural acidifying factors the impact of strongly acid deposition would be a fraction of a unit of pH as against the very strongly acidifying natural background. You would not expect damage to these naturally acid communities.

204. Before we leave forestry you did describe to us earlier on a combination of factors that affect forests, sulphur dioxide, leaching of heavy metals, ozone and all these other factors. You said it is not possible to identify one particular cause in that situation. It has been said to us that the damage that has been observed in the forests in Sweden is the result of stress. The trees are put under stress and the stress could be caused by a number of things. Having been put under stress, they then become more prone to beetle attacks, fungal attacks and the rest of it. This is causing the result of dying trees, dying forests. Would it not be fair to say in that context that there is one common factor, that is, air pollution; whether it be sulphur dioxide, whether it be nitrogen oxide, whether it be ozone, whether it be hydrocarbons, producing ozone, we are dealing with a very common cause and that is air pollution, one kind of gas or another, and their sources are identifiable—burning of fossil fuels, whether by motorcars or in power stations or in industry. The effect of that is tree stress and eventually tree damage and tree death. Would you say that would be a fair or unfair statement to make?

(Dr *Holdgate.*) I am tempted to say both, Mr Chairman. The statement that trees are showing these particular symptoms of dieback because they are stressed is almost tantologous—yes, of course. But stress or strain on the physiology of the tree can come, as you yourself have said, from many causes, Mr Chairman. It can be drought, changes in the soil, extreme low temperature. It can be infections with disease organisms, be they beetles or fungi. It can undoubtedly be air pollutants of many kinds. The statement you made was that air pollutants are universally present where forests are damaged—true. I think though you could say air pollutants are present in many areas where the forests are not showing signs of damage and that it would be difficult to find an area over the northern hemisphere where some concentrations of the substances which you mentioned are not present. So really, to carry your analogy further, one would need to look at quantification of the different factors. Having said all that, I myself as a scientist (and I think most scientists would agree) feel it is very plausible indeed that air pollution is a factor in the damage that has been observed to German forests, and we are not well up in the latest reports of damage to the Scandinavian forests. The stories have changed: rather more damage has been reported, then other causes advanced and so on. If damage is being encountered, it is quite plausible that air pollution is involved.

205. Plausible, probably or possible?

(Dr *Holdgate.*) I would want to see the data. I have not seen the latest information from Scandinavia. In Germany I would say in many parts of the country it is probable but that the dominant air pollutant involved is not necessarily the same in all those parts.

Mr Freeson

206. Are we not coming back to the point that was put by Mr Jones earlier when he said there may be all sorts of analyses of the history between the emission, the deposition and its effect, but there was a link between the two. To this, if I recall rightly, the answer was that you could not have a clear statistical relationship, but we are moving without quoting statistics back to the same question. It does seem that you accept, though with great caution, that there is a common factor, whatever the ingredients may be, varying from one country or situation to another—a general factor which we do not fully understand but which is there. It leads one from A emission to C (leaving out B for the moment) which is the death of certain forms of life. I think I know the direction to which you are pointing, Chairman, but is that a fair way of putting it? Is it not a different kind of answer from that which we have got earlier to Mr Jones's question which was very similar?

(Dr *Holdgate.*) I think, Mr Chairman, I would go with Mr Freeson. If you recall, I have spoken of three kinds of atmospheric pollutant involved to varying degrees in different circumstances and as factors of maybe varying prominence interacting with

[Mr Freeson *Contd.*]

other components in the environment in different circumstances. I would accept that air pollutants, or the ones we have been talking about, are factors in forest damage and in fresh water change in various places to varying degrees. I hope that is not too evasive—it is not meant to be.

Chairman

207. Put the question another way: if none of these pollutants were present, is the probability that we would have healthier forest in those areas where we have very unhealthy ones?

(Dr *Holdgate.*) In the Federal Republic I would say yes. I am not convinced, however—I think one must say in fact one would put it the other way round: even if there were no air pollution emissions, there would be a slow acidification of fresh waters in a number of parts of the northern hemisphere.

Mr Jones

208. Because of land use changes?

(Dr *Holdgate.*) Because of the very slow solution from the soil of substances that react with nutrients which got into those lakes in the immediate post-glacial period.

Mr Chapman

209. Because for a layman like myself we are talking in rather uncomfortable terms about the pH factor, if the pH factor goes down by 0.1 does that not mean the acidity is doubled?

(Dr *Holdgate.*) Not exactly, no. It is a logarithmic scale. It is true one unit is a tenfold increase in acidity.

210. A tenfold increase is a thousand per cent increase?

(Dr *Holdgate.*) Factor of ten, yes.

211. If one says there has been a thousandfold increase in acidity that to the layman might mean or suggest something much more serious than the pH factor being reduced by——

(Dr *Holdgate.*) That is three units. That is a very large——

Mr Chapman: I think it is very important when trying to produce a report that is understandable to laymen that these things are pointed out.

Chairman: We are moving on to water now, out of the forests into the lakes and streams.

Mr Taylor

212. Ernest Hemingway wrote a story with a title rather like that. I wonder, since Dr Holdgate has just mentioned the possibility that some of the waters of Northern Europe were becoming more acidic in any event, how great a contributory factor to that is the forestation by man which would seem to me to be a continuous process of drawing alkali into trees, acidifying the surrounding ground and then, if man was not present, of course, the tree would fall to the ground and the alkali would be restored to the soil, but when man is cultivating forests he takes the alkali—did I get it the wrong way round? I intended to say the trees were alkaline and the soil correspondingly acidic. If man is not there, the alkaline tree falls to the ground and restores its alkali to the ground. If man is there he takes a chunk of alkali away. Is this not contributing to acidity, or do you think foresters have known this for years and counteracted it?

(Dr *Holdgate.*) First of all, there is no doubt that afforestation can increase the acidity of run-off from a forest. This is partly because of the way in which the land can be prepared for afforestation. The increased drainage, the turning over of soil, even if there is not a nitrogenous fertiliser application, will increase the acidity of run-off. It is interesting to note, however—although it is on a very small sample of four lakes in Galloway—that analysis of diatom cores such as I mentioned shows that in three out of the four of those lakes the acidification, which was a well-marked transition, took place between 1850 and 1890 and probably correlated with early industrialisation in that region; the fourth catchment showed acidification in the 1920s and preceded the afforestation of that catchment. So that while manmade forests can, I believe, increase the acidity of run-off—and I think there is evidence that they have done so, for example, in Wales and possibly in Scotland—it is not the sole reason why some of the lakes like those in Galloway have become more acid.

Mr Alton

213. Are you saying that forestry methods have no bearing at all on the acidification?

[Mr Alton *Contd.*]

*(*Dr *Holdgate.)* No, I am saying that they can, but again it is not necessarily a single cause. They can.

214. Can you say a bit more about the kind of forestry methods we saw in Sweden? It was clear to all of us that this is a very big industry which results in a large, almost a forced, growth of trees, in order to grow and to cut more trees down. One got the feeling anyway that there was a certain draining of the land that would inevitably have effects ultimately on the state of the forests. One wondered if it was just a natural dying back as a result of the over-development of the forests over many years?

*(*Dr *Holdgate.)* I do not want to hesitate too much, but I am not a professional forester. I can only make a guess on this. I would suggest—because I think this is a pretty crucial point—that you might like to ask the Forestry Commission.

Chairman

215. Yes, we will be doing that.

*(*Dr *Holdgate.)* I gather you will be seeing them. Clearly, if you remove any crop with the nutrients—for example, the calcium, the magnesium, the other basic elements—contained in it, faster than weathering is releasing those nutrients in compensation in the soil, you will have a nutrient depletion process. With calcium and magnesium removal, you will have an acidification process, if at the same time there is hydrogen ion accumulation from other sources. So it is possible that intensive forestry with a lot of crop removal could aid acidification. It is also a fact that the humus under a coniferous forest tends to be more acid and to be less well-mixed into the soil layers than the humus that you get under a broad-leaved forest. These may be points you wish to pursue with the Forestry Commission.

216. We have also seen that a continued fall of acidified waters does leach out the buffers within the soil, and progressively over a long period of time the groundwater becomes more and more acid and consequently the streams and lakes also.

*(*Mr *Wilson.)* Perhaps I could go further. It almost goes without question that forests tend to be grown on very poor soils that are not agriculturally productive. Usually those areas are acid to begin with, and the forests are aggravating an already-acid situation.

Mr Jones

217. I have one question on fish and water. The CEGB have made much of the calcium deficiency argument. Is that not really just begging the question? Clearly, where you get acidification, this reduces the calcium content and is more likely to hit areas with igneous and other rocks which offer less scope for further calcification of the water. Does this really get us anywhere, using the calcium argument? Is that not part of the mechanism, rather than part of cause and effect?

*(*Dr *Holdgate.)* I would certainly agree that calcium would be part of the mechanism. Calcium is extremely important in protecting the gills of fish, which are crucially important, in their turn, in maintaining the internal concentration and proper balance of the fish. High calcium is protective: low calcium is not. Also low calcium tends to correlate with high aluminium which has in itself a direct toxic impact. So in stressing that calcium is more important than, for example, sulphate, I think my colleagues have a point. I would agree; I think that very high hydrogen, very high acid inputs, will tend also to be associated with calcium removal. It may be that Dr Everest, who is a chemist (I am just a biologist), might care to add a comment.

*(*Dr *Everest.)* Essentially, it is acidity, aluminium and calcium in balance, which appears to control fish viability. Calcium favours fish viability, but high acidity and high aluminium are detrimental. So that you have these three in play. If you have high acidity, you can protect the fish if you have a high calcium. Secondly, when you have acidic water, from whatever source, passing through your soil and bedrock, it will leach out calcium; and obviously the more lime you have present in the soil, the more calcium you will have. If the soil is deficient in calcium, then you will tend to leach out aluminium, because that is the next species that will come out with high acidity. In those circumstances, you will get a water high in aluminium and, high in acidity, which is dangerous for fish. It depends very much, therefore, on the precise catchment chemistry and on the ratio you have in your water.

*(*Dr *Holdgate.)* There is some evidence, in this Royal Society volume, from North American work that where fairly acid precipitation is percolating through the surface layers of acid soil, you get more aluminium

[Mr Jones *Contd.*]

leached from the catchment; where it goes through the deeper layers of more mineral soil, you get more calcium and magnesium coming out in the drainage.

218. This obviously raises the question of artificial introduction of calcium—that is, through liming. Do you accept that that is simply mitigation of the problems that are occurring, rather than a solution to the problems?

(Dr *Holdgate.*) I think that there is evidence that it can certainly be useful in mitigation, in, for example, keeping stocks of fish going that, on all reasonable hypothesis, would otherwise disappear. As far as I am aware, it has not been successful anywhere in completely reversing the situation. In theory, if you could do it properly, I see no scientific reason why you could not achieve a complete mitigation. However, it would not be enough just to shove the correcting calcium and neutralising capacity into the lake, because so many of the fish stocks do not actually spawn in the lakes, they tend to run up into feeder streams. You would have to make certain that you were also correcting acid pulses—spikes—which can probably have a particularly significant effect at sensitive times in the life cycle in those streams. A lot of work has been done in Scandinavia. Again, there is a lot of literature on that. I know that the general judgement of my Scandinavian colleagues is that the present state of the art is that it is a mitigation and not a complete cure.

219. Is it also not the case, therefore, that in precisely those areas where the calcium content is least, you would have to do the most liming; and that the lime is not available, except at very high economic costs of transportation, therefore the matter becomes economically an extremely difficult problem even to mitigate?

(Dr *Holdgate.*) Yes, I would think that generally that *will* be the case. Of course, by "lime" I am not only talking of people putting on agricultural powder lime. Alternative ways of incorporating lime include limestone chips or chalk rock and things of slow release. But yes, I would agree with the question.

Chairman

220. Can we come to human health now? You deal with that in paragraphs 25 and 26 of this section of your paper, Section IV. You say that there are not direct effects of acid deposition on human health. We did hear, in Western Germany, that air pollution was considered the prime suspect for increasing respiratory disorders among children. We heard too, in Sweden, that the passing of acidified water through a copper supply system caused diarrhoea amongst infants.

In paragraph 26 you draw our attention to the disadvantages of passing acidified water through lead pipes, of which we have an abundance in this country. Given all these indicators, can I ask you what research the DOE have commissioned in looking into these matters, or does that fall within the responsibility of another department?

(Dr Holdgate.) It falls, Mr Chairman, within the responsibility of the Department of Health and Social Security, who are our official medical advisers to the Department and who would commission research of this kind on our behalf if we and they in dialogue, and they in particular, concluded this was something that ought to be studied. In the UK, as this evidence shows and as you yourself are well aware, we have been giving priority to the lead problem which, for the reasons you said, is a serious problem in the UK about which steps are now being taken. We have not been aware from any of the advice that has come to us from our medical advisers of the kind of problem of copper pipes, and toxicity that has been reported in Scandinavia. As to air pollution aggravating respiratory disorders, in the past this was a serious problem in the UK as in the great London smogs and a lot of research was done on that. I am not aware that our attention has been drawn to this being a problem in British conditions for infants but we will take note of what you have said. I would be very happy to put a question to the Department of Health if it seemed clear from the German evidence that this is something we should be looking at to see if problems do occur here. Then we would be asking our medical advisers if they would consider this is something we should study.

Mr Alton: Certainly one of the things we did hear in Germany at Karlsruhe from your colleagues—and this may be anecdotal evidence—was that in Czechoslovakia quite recently young children had to be evacuated from one of the towns and given recuperation in a spa town because of the high levels of pollution over that area. When we were in Sweden we were told about the

[Chairman *Contd.*]

danger of the mercury build-up in fish and the dangers to pregnant women as well, which they attributed directly to the acid emissions through rain into their lakes. Perhaps you could comment on that and say whether or not you think it is serious enough anecdotal evidence to warrant the DHSS looking into that problem.

Mr Jones

221. And cadmium at the same time?

*(*Dr *Holdgate.)* I would have to see what is behind the anecdote and I would want to discuss with our particular specialist toxicologists the situation in Czechoslovakia. We know that very high concentrations of sulphur dioxide can occur in parts of Czechoslovakia, as in the German Democratic Republic, from the burning of high-sulphur local coal, producing a quite local air pollution problem of the kind we used to get in London, but I would like to see the evidence. As to mercury and cadmium, mercury in fish is a problem that has been reported extensively for a long period of time but was ascribed, I think I am right in saying, to mercurial fungicides.

Chairman

222. What we were told was that it was pike and bream, predatory fish, that accumulate mercury.

*(*Dr *Holdgate.)* Methyl mercury is known to achieve the highest levels in pike but the best hypotheses on the cause have involved the conversion by bacteria of the mercury into its soluble state from either an industrial source, such as the chloralkali industry, which the Swedes do not have any more, in the old mercury cell form, or from mercurial fungicides, which again they have phased out. I would want to look further into the evidence. I would want to know where the mercury was coming from in these circumstances, and the same would be true of cadmium. I prefer not to comment further on those hypotheses without testing and examining.

Mr Jones

223. Will you pursue it and come back to us on it?

*(*Dr *Holdgate.)* If I may ask you a question, Chairman, if you were in the course of any particular evidence to come across anything which you clearly wanted to pass to us, we would be extremely grateful for inputs on this and I would be happy to ask the relevant specialists to look at it.

Chairman

224. We would be happy to let you have the great pile of written evidence we have accumulated.

*(*Mr *Wilson.)* One hates to disagree with one's Chief Scientist but there is one correction. The Department does have some responsibility in this on the water side for water quality. We have asked our water department to look in one of the research topics they already have on upland management to incorporate some work into looking at the mobilisation of heavy metals into water supplies in remote areas that are not on public water supplies, so we recognise that there is a responsibility there for the Department and are trying to do something about that. The other thing is the question of the German health experience, which perhaps you have heard of. This probably relates to a recent article in one of their journals about cot deaths and trying to tie in acid deposition with cot deaths. We have a copy of the article and we put it to our experts at the DHSS and are awaiting their reply to see if there is anything relating acid deposition to the incidence of cot deaths. This is yet another suggestion trying to explain this rather unknown phenomenon.

225. I will ask our Clerk to write to you on the evidence we received in Germany.

*(*Dr *Eggleton.)* I would suggest the Committee directs this question of cadmium and mercury to MAFF. They are carrying out studies on the content of mercury and cadmium in diet in this country, but, in fact, at Harwell we have had a group involved in the mercury study who have been obliged to eat large quantities of halibut in order to test the uptake. It is a matter which concerns them considerably, though not in connection with acid rain.

*(*Dr *Holdgate.)* My sympathy for my colleagues would be the greater if they had to eat a diet of salmon!

Mr Freeson: Arising from this, we have had some very interesting supplementary points just put following that earlier answer and we as a Committee would be only too happy to provide whatever information we can to assist in this work. It does bring me back to earlier questions. If the Swedish

[Chairman *Contd.*]

experts, rightly or wrongly, are making these assumptions or putting these questions and if the Germans are doing it and others are doing it, may I put it quite simply and bluntly: why the hell should we wait until we ask you questions picked up over there before there is some kind of relationship between work being done in the DOE or elsewhere and work which is, I presume, being done in Sweden or Germany or elsewhere? I come back to the proper use of the word "communication". We have heard a great deal about seminars and conferences and contacts but communication is something different. Why is it that you have to wait, with all due respect to the supplementary points we have just had, until Members come back from such visits and put questions to you and you then ask us to provide that information before you can proceed to do further work?

Chairman

226. That is the penalty of trying to be helpful!

*(*Dr *Holdgate.)* I am very glad that my two colleagues at least were able to reassure you that we are doing two bits of work, of which I was unaware, which in part answered this question. The other thing I would say is that it is very possible that if you had before you a specialist in the health effects area, in toxicology, you would find they were aware of things I am not aware of, just as I was not aware of what my two colleagues added either, so Mr Freeson's perfectly fair if somewhat barbed points might have been better deflected by their shield than by mine.

227. Could we leave health and come to the question of materials and buildings. You have just let us have, but most Members did not receive it until this afternoon, a further paper headed, "Effects of Acid Precipitation on Buildings". It would be helpful if you or somebody in your team could talk to that paper as we have not had a chance really to take it in.

*(*Dr *Holdgate.)* Could I introduce Dr Everett, who is a Senior Principal Scientific Officer in the Building Research Establishment and heads the part of that establishment which has been particularly concerned in this area. I think between him and Mr Wilson we may be able to help you.

*(*Dr *Everett.)* The paper is intended to show that the deterioration of certain building materials has been going on for generations, in fact for hundreds of years. In the building in which we are now sitting, 20 years ago the stone was being replaced because of deterioration and the same has occurred in St Paul's. So the first point I think we would make is that the deterioration of natural stone is not something that is very new, it has been going on for generations. The real question is, of course, whether in modern days it has increased and that is something that is very difficult to determine because the causes of the decay of stone are many. It is not only the effect of the environment, but the effect of frost and the effect of what is called crystallisation: that is, salts within the stone that come to the surface and crystallise. When they crystallise they expand and they force off parts of the stone. So this process goes on irrespective of the atmosphere; it is controlled by humidity and temperature. Atmospheric pollution can increase the amount of salt that is in the natural stone and this point is made in the paper as well, but it does not increase it proportionately and you will find on page 2, where it refers to experiments that lasted for ten years, between 1955 and 1965, on specimens of portland stone—and I would remind you St Paul's Cathedral is made of this stone—these specimens were put out here at Westminster and at the Building Research Establishment at Garston near Watford in a rural area. The difference in the sulphur dioxide concentration in the two sites is five to 12 times—it depends on the time of year at which you measure it; but the actual deterioration that had occurred between the rural environment and the polluted urban environment was only two and a half times. Two and a half times is significant; but it is not five to 12 times, which is the point I think that needs to be noted. The Establishment has been working on the decay of stone for perhaps 40 years on and off, as resources permit, and the 10 documents give a history of what has been found—the causes of the decay as it was originally hypothesised and the changes throughout the years as more research shows up other factors, on how these initial hypotheses have been changed. You will find all that in the documents which I have put forward to you. We have very recently become involved closely with acid deposition; a research programme has started at the Building Research Establishment but we have been involved for the last four years with other activities that have

[Chairman *Contd.*]

gone on in London, particularly with St Paul's, in trying to determine the rate of decay of the stone. It was fortunate that Sir Christopher Wren, when St Paul's was built, bored holes in the stone so that the cables to hoist the stone into position could be threaded through these holes. When the stones were in position these holes were filled with molten lead and it served the purpose of keying the blocks of stone together. The decay has lowered the surface of the stone but retained the surface of the molten lead plug, so one is able to measure the rate of decay.

228. That only tells us the stone is eroding faster than the lead. Are you saying the lead has not dissolved at all?

*(*Dr *Everett.)* Virtually none—not in that environment. If it is very, very acid, then it will, but the lead plugs are quite substantial so that the reduction in the height of the plug is very little, if one examines the balustrade in St Paul's Cathedral erected in 1717. We have a datum point to work from. These lead plugs are now standing proud of the stone by about 8 to 30 mm; in the last 240 years or so one can calculate the rate of attack. The average rate—if there is such a thing as an average rate—is around about 0.078 mm a year.

229. That is assuming the corrosion started immediately the building was put up. Are we certain of that?

*(*Dr *Everett.)* We are not absolutely certain of that; but there is no indication that on that building over the last five years there has been an increased rate of attack. If one takes the most charitable rate of corrosion at 0.1 mm per year, in five years we should be half a millimetre down, and we are not. I am not saying that atmospheric pollution does not increase the rate: what I am saying is that at least one building in the London area, the rate has not substantially increased, and there is a paper——

Mr Chapman

230. On this very technical matter, could I ask (and we all have one thing in common with Sir Christopher Wren—he also was a Member of Parliament) if you would agree with this: that really in this area it would pay us economically to use a harder stone if we are building in a London environment and not a rural environment rather than a cheaper stone? From that, is it right to say that granite and portland stone are hard stones whereas sandstones are softer stones? One of the great mistakes of this Palace, I am told, is that people chose the wrong stone, a stone that was too soft. The damage on the river front of this Palace is quite enormous.

*(*Dr *Everett.)* I will try to answer that question, but it is not quite correct to say that the harder the stone the more durable it is, because that depends on what is called micro-porosity, the number and size of the pores in the stone. If the micro-porosity is very high there are a lot of very fine pores in the stone and then the tendency to frost damage increases. Certain granites are excellent in this respect, but all the granites in this country will, of course, emit radon so you are sacrificing one concern for another. The hard limestone from which this building is built is quite durable and, if the right stone is chosen, there is no reason why the decay should be accelerated.

Chairman

231. One thing I am looking for, if it is at all attainable, is some idea of the relative costs of doing something and doing nothing to remove sulphur emissions from the atmosphere. Let me put it this way: if we do nothing at all, corrosion of our buildings will continue partly from this particular cause. How many buildings are there in the United Kingdom that are susceptible to this kind of damage from this particular cause? What will be the cost to the community as a whole of making good that damage? How does that compare with the cost of desulphurisation? I do not know whether it is possible to find the factors in that equation or not, but if it were we would be very interested to have them.

*(*Dr *Everett.)* Yes, I appreciate that, Mr Chairman. You have only mentioned one option, that is, of getting rid of the sulphur dioxide in the air. There are many others. If you want to get rid of the sulphur dioxide you stop all internal combustion engines, so the city comes to a halt. If you close down all the power stations, even that will not give you the security you want, because the sulphate that has already penetrated our stone buildings, but the——

232. We know there is the background content in the atmosphere.

[Chairman *Contd.*]

(Dr *Everett.*) The other option, Mr Chairman, is to protect the buildings themselves and again I have gone into that.

233. Have we got the cost of that?

(Dr *Everett.*) It is expensive—it is something like £5 a square metre—but it will give you the protection that you need.

234. How many buildings, at £5 a square metre, do we have to cover in the United Kingdom, how long will that last, and how does that compare with the cost of putting in a high-pressure fluid base in your power station?

(Dr *Everett.*) There will be many thousands of buildings; there will be many hundreds of thousands of square metres that you would need to protect.

235. We do not know, is that the answer?

(Dr *Everett.*) That is the basic answer, yes: we do not know.

Mr Alexander

236. You have said in your paper that the erosion rate on these interesting studies you have done over five years is 0.078 millimetres a year?

(Dr *Everett.*) Yes.

237. The concept of acid rain is a reasonably new one; probably five years ago people did not know anything about it at all, except the scientists. Is there any evidence, from the admittedly short study you have done, that the corrosion is proceeding exactly at the same rate every year, or is it getting greater or less?

(Dr *Everett.*) The answer to your question is that there is no evidence on buildings, but in laboratory tests, when you increase the acidity of the environment, you will increase the rate of decay of stone; but the rate of corrosion levels off above some undetermined concentration.

238. Presumably your studies will look particularly over the years to see if there is any change?

(Dr *Everett.*) Yes. What one is trying to look for now is the synergistic effect of NO_x and SO_2, as against the separate entities. This is the new factor that has come into the equation.

Mr Jones

239. Since the paper seems to be based more or less entirely on stone, could I ask about concrete? You have talked earlier on about micro-porosity. Is it not the case that modern concretes, because of their use of lime rather than the old-fashioned ash method, have much looser hydroxyl ions which are therefore more easily flushed out, therefore they are more prone to sulphate attacks of various kinds?

(Dr *Everett.*) More easily, yes.

240. Therefore, since for every one St Paul's there are hundreds of tower blocks, would it not be more advantageous to the Committee, in coming to a total for the cost of aerial pollution, to have some estimate of the damage to that sort of material?

(Dr *Everett.*) The damage done to concrete from the SO_2 levels in the environment is very little, because the SO_2 that gets into concrete is tied up very quickly to form a compound called Ettringite which is insoluble in concrete, and once it is formed the SO_2 plays no further part. The problems that you are referring to are not due to acid deposition but to the vapour permeability of the concrete to another pollutant in the atmosphere—carbon dioxide, CO_2. What this does is to go through the pores in the concrete; because it reacts with the hydroxyl ions that are there, it reduces the pH, and it reduces the pH from about 13 units—which is normal in fresh concrete—down to 8.3 units, so there is a substantial drop in the pH range. It is a many thousand times reduction in alkalinity. When the carbonation front reaches the steel—the reinforcement in the concrete—then it enables the steel to corrode under the normal corrosion processes.

Mr Taylor

241. It oxidises?

(Dr *Everett.*) It oxidises to rust—iron oxides. The rust occupies about 5 times the volume of the original metal, so the concrete is put under a very high internal stress and it breaks, it fractures. A crack is produced that follows the line of the reinforcement. Once a crack is formed, then the carbon dioxide in the air can go in much more quickly and can cause further damage to the embedded steel. So we are, in a way,

[Mr Taylor *Contd.*]
confusing the two ideas of acid deposition and penetration of dry CO_2.

Chairman

242. We are running into a more difficult problem then. How are we placed with our motorways, with all these flyovers that are made of concrete, and with all the carbon dioxide that the motor cars going over them are emitting? Where are we with our tower blocks, many of them built with the industrialised method of concrete? What kind of lifespan do these structures have in these conditions, and when are we going to have to start replacing them all? The capital cost is almost staggering, is it not, if what you say is right?

(Dr *Everett.*) Yes, it is. However, when you build a viaduct over a motorway you take this into account, by making sure that that concrete is *very* dense and that the number of pores—the permeability of the concrete—is very low, so that carbon dioxide cannot get in. With some tower blocks that were put up by prefabricated building, the concrete was not perhaps of the best quality, it was porous, and because of its porosity the atmospheric carbon dioxide has got in, the corrosion has occurred and the damage is produced.

243. The sooner we find an electric motor car, the better!

(Dr *Everett.*) No comment!

Mr Alexander

244. Are you able to say how many buildings there are in this country over, say, 20 years old, which are affected in some way by acid deposition, and what proportion that would be likely to be of the whole?

(Dr *Everett.*) There is no evidence that any building is affected by acid deposition. There is evidence that there are many stone buildings and that there are some metal buildings that have decayed as a result of atmospheric pollution. Whether that pollution is acid rain as such—that is what we are attempting to find out.

Chairman

245. Thank you very much. That is very helpful indeed, Dr Everett. I wonder if we could have a round-up on this question of overall cost, by taking the last paragraph of this Section IV of your paper, Dr Holdgate. I think it is for you, is it not?

(Dr *Holdgate.*) Yes.

246. There you set out the EEC figures under various heads such as loss of revenue from tourism and sport, and there is an item there for building costs of £350 million to £1,900 million per annum, if I have read the figures correctly. Have you any comments to make at all on these EEC figures?

(Dr *Holdgate.*) What I would say is that we quoted these figures from Environmental Resources Limited, simply because they are the latest figures. They draw heavily on some calculations done by OFCD. We would emphasise our view that, as we say in paragraph 29, they must be considred as extremely uncertain. It is partly for this reason that the United Kingdom has consistently been pressing, within the Long Range Transboundary Air Pollution Convention (the Geneva Convention), that there should be an effort to look more strictly at the costs and benefits that might be associated with transfrontier air pollution and therefore acid deposition. I have somewhere behind me Mr Sinfield who is actually looking after our input to this work with the Convention, and he will be able to answer any questions on that and, indeed, on this cost-benefit field, if you like.

247. Then we need not trouble you at all. The only thing I would like to say, rather than ask a question, is that it became quite clear, from the discussion we were having a moment ago on the cost of buildings, that we do not really have very much information at all. I would have thought that if Government has to make a decision at some time or other, in public expenditure terms, in dealing with this particular problem, it would want to know both sides of the equation. Would it not be helpful to Government if someone made a stab at trying to find out what the cost of making good the effects of pollution—whatever it is—upon our buildings are?

(Dr *Holdgate.*) I would entirely agree, Mr Chairman. Of course, it is this concern that we should at least get a better notion of both the damage costs and the control costs, that has led the United Kingdom to press very much that this *should* be done within the European context.

[Chairman *Contd.*]

Mr Sinfield can tell us what the work encompasses, as we have some work commissioned.

*(*Mr *Sinfield.)* Yes, Mr Chairman. At the moment we have a research project let with consultants. The total value of this work is £30,000 in the current financial year. The purpose of this contract is to establish a cost-benefit methodology. You will appreciate, of course, from the meetings you have had already the great scientific uncertainty in this area and, of course, one of the features of the cost-benefit methodology will be how to cope with uncertainty in the scientific field, and the value judgments that emerge from the political process. Conventional cost-benefit techniques are generally inadequate in this area. That is why we are developing alternative approaches and establishing economic cost-benefits in this field. As I say, we have a research project under way at the moment and, as has already been mentioned, probably the main forum in which we are applying this new methodology is the United Nations Convention. I was Chairman of the group of experts meeting in Geneva last week and we will be reporting, or I will be reporting, to the second session of the executive body meeting in September about the work programme that we would propose in terms of establishing the cost and benefits of a programme of SO_2 abatement.

*(*Dr *Holdgate.)* I may ask my colleague, is there any difficulty in providing this Committee, if they so wish, with a copy of your report when complete?

*(*Mr *Sinfield.)* We could certainly supply a copy of the report, the official report, of course, from Geneva, and we could supply any other documents you may care to see on the methodology that we are developing, its purpose, the background to the development of methodology, the work being done by consultants.

248. Thank you very much indeed. We will bear that in mind. There is one area we ought to touch upon and that is international responsibilities, because you will be advising Ministers as to how they could respond to the various pressures that are building up and we detected some in Sweden, great dissatisfaction that we had not joined the 30 Club. I wonder how you see our position in the world in regard to these matters in view of what is being said about us overseas?

*(*Dr *Holdgate.)* Mr Chairman, quite clearly you may wish to explore the more government policy aspects with my Minister, Mr William Waldegrave, who will be coming to give evidence on a further occasion, so if you do not mind I will try in reply not to touch on those points which are more appropriate to the Minister. I would say one of the great preoccupations of all those in the UK who have been engaged in this area has been to try, as far as possible, to approach the subject in an honest, dispassionate, factual way. It does not mean that we have not been sensitive to the very real concerns of our colleagues, for example, from Scandinavia and the Federal Republic of Germany, and we do not doubt that they have been sustaining environmental damage which they consider can be traced—and this goes back to our earlier exchanges—at least in part to air pollution. We have been trying within the context of an understanding and constructive approach to develop ways towards the solution of this problem that really address the variable factors that are susceptible of effective control, with control technologies that are cost-effective, which take the costs of the damage into account alongside the cost of the control, and generally steering our way towards getting it right. That has been our overall aim and I hope that we are consistent in that respect and will continue to be in the future. In approaching something like a 30 per cent Club, clearly the benefits and the feasibilities and costs of going for a particular target of abatement have to be weighed up in that sort of context.

249. I do not know whether I should put this question to you but do you know when the Council of Ministers will consider the draft directive on emission control, and will we by then as a country have come up with a firm view on that?

*(*Dr *Holdgate.)* The first part of the question is easy to answer. The Environment Council meet on 28th June in Luxembourg immediately after the conference in Munich that the government of the Federal Republic of Germany is convening. This meeting will be the first time the Council has had the opportunity of considering the Commission's draft directive, the large plant directive. Members will be aware that that proposes a 60 per cent SO_2, 40 per cent NO_x and 40 per cent particulate abatement from certain large plants as defined in the draft directive. It will also be the first time that

[Chairman *Contd.*]
the Commission's notions on the reduction of vehicle emissions will have been before the Council. Clearly what happens on that occasion and how it is handled is for Ministers but I think that observers of the European scene will expect that what will take place on this first occasion will be more in the character of a second reading debate in which the different delegations will make their views known and there will be an exchange in the corridors as well, after which the processes of negotiation can begin. It is very unusual in the European context for a draft directive not to require to go in and out of the council of Ministers on several occasions before it reaches a final, agreed solution, but I think Mr Waldegrave by the time he appears, which will be after that meeting, will be better placed to give you a briefing on what has happened and to answer policy questions.

Chairman: Thank you, Dr Holdgate. I think we have exhausted the Committee as well as you and your colleagues. Thank you very much indeed for coming.

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Sir Hugh Rossi, in the Chair

Mr Richard Alexander
Mr Sydney Chapman
Mr Chris Smith

INQUIRY INTO "ACID RAIN"

Warren Spring Laboratory

INTRODUCTION

1. Warren Spring Laboratory is a Research Establishment of the Department of Trade and Industry. The Laboratory's Air Pollution Division carries out research on contract to the Department of the Environment and to other government departments, industry and other customers. Studies relevant to the subject of acid rain have been carried out by WSL for a number of years. Since 1980 it has chaired, provided the secretariat for, and contributed to the United Kingdom Review Group on Acid Rain whose report "Acid Deposition in the United Kingdom"[1] is provided to the Environment Committee with this memorandum. The memorandum summarises the factual information collected in the report and the broad conclusions which the Group reached as to the nature and origin of the phenomenon in this country. Reference is also made to present and future research by WSL following consideration of the Report by the Department of the Environment which commissioned it.

ACID DEPOSITION

2. Strictly speaking the term "acid rain" should only be applied to the acidity (or hydrogen ion concentration) of precipitation. However, the term has been rather loosely extended and, as now commonly used, incorporates the concentration in precipitation of other ions relevant to acidity and the dry deposition of acidic species. The term "acid deposition" is therefore more appropriate in most cases, unless the pH of precipitation is being specifically referred to.

3. Precipitation is often considered to be acid, rather arbitrarily, when the pH is less than 5.6, ie the pH of deionised water in equilibrium with carbon dioxide (340 ppmv). However, a pH below 5.6 does not necessarily imply the influence of man's activities; pH values might range from 4.5 to 5.6 due to the variability of the natural sulphur cycle alone.[2]

4. There has been growing concern that acid deposition, resulting primarily from emissions of oxides of sulphur and nitrogen, is having adverse effects on sensitive ecosystems in locations remote from major source regions. These emissions may undergo complex chemical reactions forming sulphuric and nitric acid respectively before being transported to the earth's surface.

5. Three major pathways exist whereby pollutant species may be transported to the ground: by a hydrometeor (rain, snow, hail etc), termed *wet deposition*; deposited directly, termed *dry deposition*; or captured by the impaction of cloud or fog droplets on to vegetation, termed *occult deposition.* The term *acid deposition* encompasses all these processes.

The cost of printing and publishing these Minutes of Evidence is estimated by Her Majesty's Stationery Office at £2,400.

CURRENT RESEARCH AT WARREN SPRING LABORATORY

6. The Air Pollution Division of Warren Spring Laboratory carries out research in several areas related to acid deposition. These are calculating national emission inventories of sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and total hydrocarbons; measuring emission factors of NO_x, CO and total hydrocarbons from mobile sources and assessing technology for the reduction of such emissions and the resulting effects on air quality; numerical modelling of pollutant dispersion and transformation; co-ordinating the United Kingdom smoke and SO_2 monitoring networks; and some measurements of ambient NO_x and ozone (O_3) concentrations. Two areas are of particular relevance to this memorandum. The first is WSL's work on the monitoring of precipitation composition and related species at rural sites. This has been incorporated in the Report of the Review Group and provides direct information on *wet* deposition, while measurements of SO_2 and particulate sulphate concentrations at the sites provide an input to the calculation of *dry* deposition. The second involves the assessment of the performance and costs of technologies for the abatement of SO_2 and NO_x emissions from combustion plant. Work is still in progress on this subject and information can be provided to the Committee when practicable.

7. Warren Spring Laboratory began measurements of precipitation composition for the DOE as part of an OECD study on the long-range transport of air pollution in 1973. The present phase of research started in late-1977, with the commencement of the United Nations Economic Commission for Europe's European Monitoring and Evaluation Programme (EMEP).

8. Initially the measurement programme was confined to pH, SO_4^{2-}, Na^+ and Mg^{2+} in precipitation, SO_4^{2-} aerosol and SO_2 gas at just one site. The programme has been expanded considerably, however, and now daily precipitation samples from five sites (Fig 1) are analysed for all major ions (pH, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, Mg^{2+} and Ca^{2+}). Dichotomous samplers are now used to fractionate the collected aerosol into <2.5 μm and 2.5–15 μm fractions which are then analysed for SO_4^{2-} (and on occasions NO_3^-, Cl^-, NH_4^+ and Na^+). SO_2 concentrations are also monitored at each site.

9. As part of this monitoring programme an automatic refrigerated "wet-only" precipitation collector has been developed. As the name implies this collector opens only during periods of precipitation and minimises the contamination of the samples due to processes such as dustfall on to the collector surfaces; refrigeration greatly reduces chemical changes in the collected rainwater.

10. These measurements form the United Kingdom input to EMEP. In addition, the Laboratory participates fully in the intercomparison exercises and Chemical Expert Group meetings within the EMEP.

11. In addition to its own monitoring activities, and in order to improve spatial coverage of the country, the Laboratory has placed a contract, on behalf of the DOE, with the Field Studies Council for pH measurements of precipitation at ten sites (Fig 1) in England and Wales beginning in October 1983.

12. In 1980, at the request of the Department of the Environment, the Laboratory invited a small group of United Kingdom scientists active in research into the physicochemical aspects of acid rain to review available data primarily for the United Kingdom. Their terms of reference were as follows:

(i) to examine the distribution of acidity in precipitation in the United Kingdom on the basis of existing measurements.

(ii) To assess the quality of available data for precipitation acidity in Northern Europe and to examine the evidence for trends with time.

(iii) To assess the need for further research programmes.

13. The Review Group published a preliminary report in 1982 and the full report "Acid Deposition in the United Kingdom" in December 1983. The evidence on the distribution of acid deposition presented in sections 14–34 is largely drawn from this report.

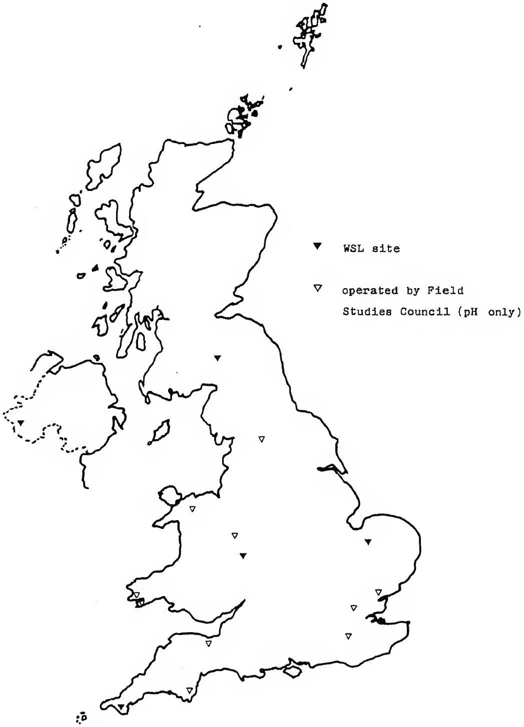

Figure 1 Location of monitoring sites

CONCLUSIONS BASED ON CURRENT UNDERSTANDING

14. For the period 1978 to 1980 available data of acceptable quality have allowed a map of acidity in precipitation to be drawn for ~60 per cent of the land surface of the United Kingdom. The map (Fig 2) shows a gradient of increasing acidity from west to east, average concentrations ranging from 20–40 μeq litre^{-1} (pH 4.7–4.4) in the west to 50–75 μeq litre^{-1} (pH 4.3–4.1) in the east. The highest measured values were found at two sites in south-east England.

15. A map of the wet deposition of acidity (Fig 3) has been obtained from the product of hydrogen ion concentration and the 30-year average rainfall. For most central and eastern parts of the mapped area the annual wet deposition of hydrogen ion is in the range 0.025–0.075 gm^{-2} year^{-1}. The areas with the largest predicted deposition are parts of Cumbria, the west Central Highlands and the Southern Uplands of Scotland, and here deposition is in the range 0.075–0.15 gm^{-2} year^{-1}, of the same order as regions of Scandinavia and North America. The largest values occur in areas of high rainfall and have not been measured but have been inferred by extrapolation from measurements made in areas of lower rainfall.

16. The distributions of non-marine sulphate and nitrate in precipitation over the country are similar. Like acidity they exhibit a general increase from west to east but the increase is much greater; unlike acidity, the highest measured concentrations are in the east Midlands (~120 μeq litre^{-1} for SO_4^{2-} and ~60 μeq litre^{-1} for NO_3^-) with lower concentrations in south-east England.

17. Maps of the wet deposition of non-marine sulphate (Fig 4) and nitrate (Fig 5) show that, like acidity, the largest predicted deposition (2.8 gSm^{-2} year^{-1} and 0.5 gNm^{-2} year^{-1}) occurs in the regions of highest rainfall.

18. Only limited data are available for ammonium but suggest that concentrations in precipitation in the east Midlands and south-east England are greater than those further west and north. The data also indicate that the deposition of ammonium is similar to nitrate over large parts of the country (when both are expressed as nitrogen).

19. The pattern of precipitation acidity in the United Kingdom is generally consistent with the broad distribution for Europe. This indicates weighted annual mean acidities of around 100 μeq litre^{-1} (~pH 4.0) in central Europe, with less acid values towards the coasts.

20. Information about acidity in urban areas is sparse. In three United Kingdom cases, a mean excess of about 15 μeq H^+ litre^{-1} over the regional values is indicated, but no general conclusions can be drawn from such limited data.

21. The acidity of a precipitation sample cannot be uniquely apportioned among the anions detected by chemical analysis. Comparison of a large number of samples distributed in space and time, however, permits statistical correlations to be made, from which it may be inferred that the most likely annual average contributions to acidity in northern Britain are 70 per cent from sulphuric acid and 30 per cent from nitric acid.

22. There are annual cycles in the composition of precipitation in the United Kingdom, the amplitude and phase of which vary somewhat from site to site and year to year. The general pattern is for spring maxima in H^+, SO_4^{2-} and NO_3^- concentrations. These are out of phase with the winter maxima observed for SO_2 and NO_x concentrations. The annual cycles in deposition are less pronounced than those in concentration.

23. At Warren Spring Laboratory sites, and a few others, analyses are made on a daily basis. They show high variability, with the more acid rain events usually being associated with air trajectories which have traversed the industrial areas of the United Kingdom and Europe. The frequency distribution of the deposition of acidity reveals that a large part of the annual total acidity is deposited on a few days in the year, typically 30 per cent in five to six days. The depositions of nitrate and sulphate are similarly episodic.

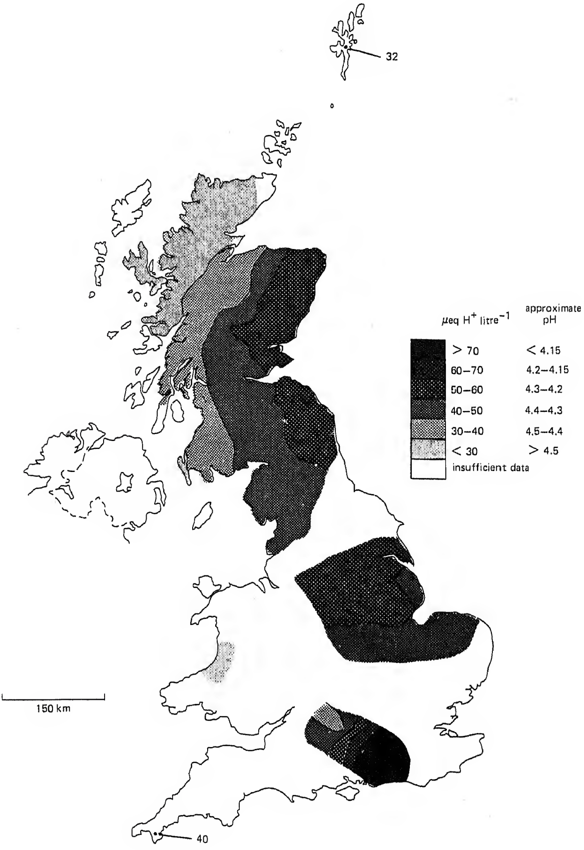

Figure 2 Rainfall weighted annual average hydrogen ion concentrations

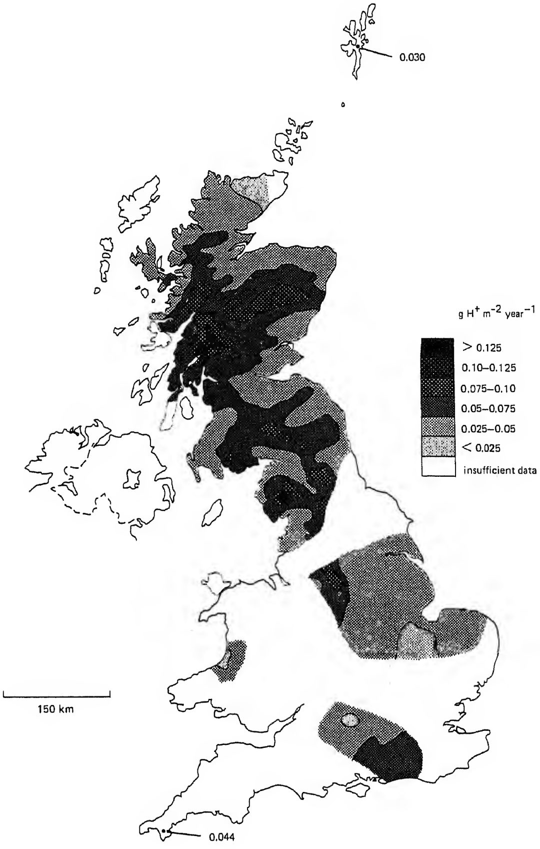

Figure 3 Deposited acidity

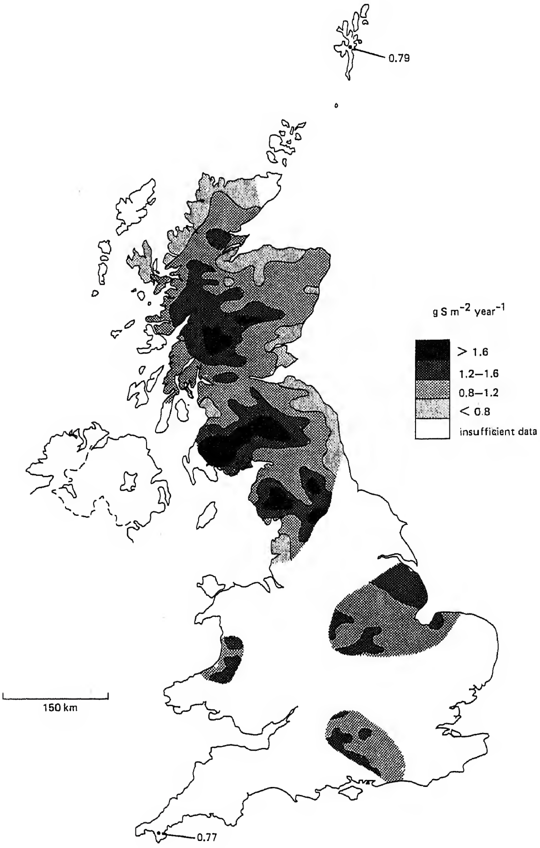

Figure 4 Deposited non-marine sulphate (as sulphur)

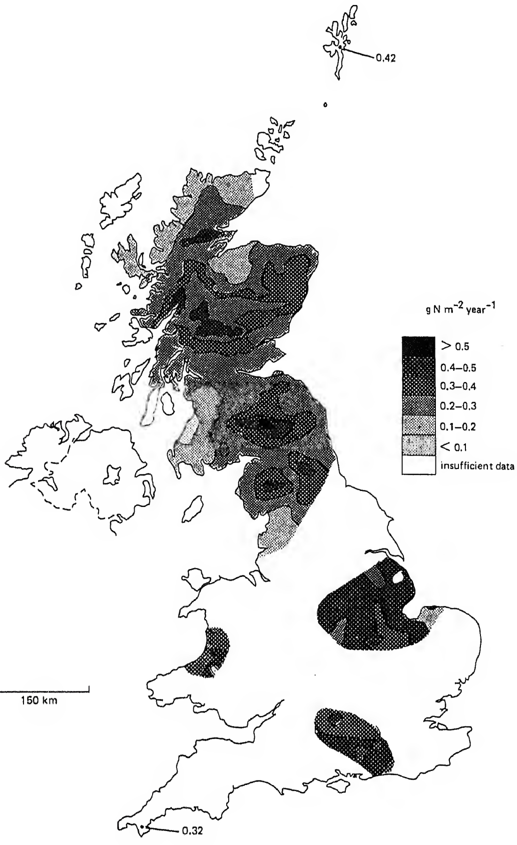

Figure 5 Deposited nitrate (as nitrogen)

24. Dry deposition is an important means of transfer of pollutant species to the earth's surface. The annual input of sulphur by this mechanism to Great Britain has been estimated from a combination of modelled sulphur dioxide concentrations and values for the deposition velocity deduced from a land-use classification. The resulting map (Fig 6) shows that dry deposition is greatest near to major source areas and exceeds wet deposition for most of central, southern and eastern England and central Scotland. Sulphur dioxide is an acid gas and the maximum potential input of acidity from this mechanism represents the major input to acidity over large areas of Great Britain. A complete picture of dry deposited acidity requires information for other acid and alkaline species which is not available at present.

25. Modelling exercises as part of the European Monitoring and Evaluation Programme (EMEP) show that 80 per cent of the total deposition of sulphur (wet and dry) in the United Kingdom originates from indigenous emissions; the next largest contribution is characterised as "undecided". There are three possible sources for this contribution: natural sources, sources outside the European region or sulphur emitted in Europe at an earlier time than that considered in the EMEP model.

26. An approximate sulphur budget for Great Britain indicates that about 25 per cent of British emissions are deposited in Great Britain, the partition between wet and dry deposition being about 1/3 wet and 2/3 dry. Considering the extrapolation procedures involved, however, this calculation must be regarded as very approximate.

27. Past United Kingdom data on the composition of precipitation from as long ago as 1861 have been examined. In general the quality of these data and the lack of continuity of the measurements have prevented any reliable quantitative estimates of changes over time being made.

28. Analysis of past data from the three United Kingdom sites in the European Air Chemistry Network showed that the application of quality control measures greatly affected the number of acceptable monthly data points. Variations in acidity could not be explained in a physically sensible way by correlations with sulphate or nitrate, and the data cannot therefore be used for reliable attribution of trends.

29. The deposition of non-marine sulphate over the period 1965–75 remained constant or decreased at most sites in the European Air Chemistry Network and did not correspond with the increase in total European sulphur dioxide emissions. Most of the data covering the longer period 1956–76 come from Scandinavia, in areas remote from major European sulphur dioxide source regions. There is some evidence that the deposition at these sites increased broadly in line with the increase in emissions over the period. There are, however, large fluctuations which give rise to considerable uncertainty. Statistical analysis of shorter data runs from a wider range of sites produced relatively few positive trends which reached statistical significance. Nevertheless there was an overall indication of increasing values. There was a much higher proportion of significant positive trends for nitrate than for sulphate or acidity in precipitation. It is evident that the raw European Air Chemistry Network data are of only limited value for the study of long-term trends.

30. Measurements of particulate sulphate and nitrate concentrations at one site in southern England show large fluctuations due to meteorological factors. Over the period from 1957 sulphate shows no significant trend while nitrate has increased on average by 3.7 per cent per year. The rate of increase in summer concentrations is greater than that for winter.

31. Data for United Kingdom emissions of sulphur dioxide from 1850 and oxides of nitrogen from 1900 are available. Both have increased considerably during the twentieth century. Sulphur dioxide emissions reached a maximum in the mid-sixties and thereafter decreased sharply. Total NO_x emissions, which are more uncertain, continued to rise until 1980.

32. The most convincing evidence to emerge from an examination of trends in United Kingdom contamination is of increases of nitrate concentrations in air and rain during a

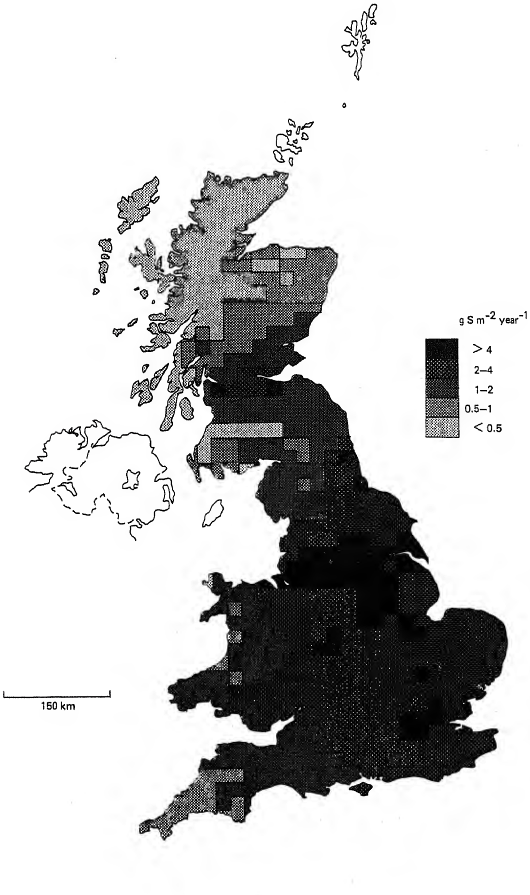

Figure 6 Dry deposition of sulphur over Great Britain

period of increasing NO_x emissions. There is also evidence of an increase in rainfall acidity but the limitations of past data in quantity and quality are such that no detailed relationships between emissions and pollutant concentrations can be identified.

33. Warren Spring Laboratory data on current United Kingdom emissions of SO_2, NO_x and total hydrocarbons and trends over recent years are summarised in Tables 1 and 2 and shown in Figs 7 and 8. At present, approximately 65 per cent of SO_2 emissions come from power stations while for NO_x the corresponding figure is ~45 per cent with a further ~30 per cent originating from motor vehicles.

34. Warren Spring Laboratory has, on behalf of DTI and DOE, been reviewing current technologies concerning methods for the control of NO_x and SO_2 emissions from large combustion plant. New techniques including advanced gravity separation, microbial leaching and systems for the rejection or redistribution of sulphur together with limited flue gas desulphurisation are being reviewed. Proposals for a test cell to study control equipment have been submitted to MEE Division of DTI and a programme of work on coal desulphurisation is under consideration.

FUTURE RESEARCH AT WARREN SPRING LABORATORY

35. The DOE have requested the Review Group on Acid Rain to advise them as to how some of the recommendations in their report might best be implemented. It has been decided to divide monitoring activity into two classes, called primary and secondary networks. The Review Group will define the nature and extent of these networks.

36. The primary network will provide high quality data on precipitation composition and related parameters at a limited number of sites (10–15) throughout the country over an extended period (20 years) and allow, *inter alia*:

—the determination of trends with time
—the attribution of sources
—validation of a wider secondary network.

37. The secondary network will operate for a shorter period and provide the regional patterns of the concentration and deposition of acidity (and other major ions) in precipitation over the United Kingdom.

38. It is expected that tertiary networks will also be set up by individual organisations for their own purposes; by their nature, however, these do not form part of a national network.

39. The DOE has asked the Review Group to provide operating protocols for the primary and secondary networks to ensure that valid and comparable data are obtained.

40. During 1984 Warren Spring Laboratory will increase its number of sites forming a basis for the proposed primary network. At each of these sites measurements of precipitation composition and related species will be carried out on a daily basis using the "wet-only" precipitation collector designed by the Laboratory. These results will continue to form the United Kingdom input to EMEP.

41. It is envisaged that the secondary network will consist of sites operated to an agreed protocol by a number of organisations. Hence, frequent intercomparisons of analytical methods and central co-ordination and quality assurance will be essential. Warren Spring Laboratory will undertake this role as the network is established during 1984.

42. Inevitably several years' data will be necessary before it will be possible to carry out a mapping exercise based on these primary and secondary networks. In the meantime, the Review Group will make use of available measurements to update their report by preparing a supplement including maps for the period 1981–83. It is unlikely, however, that the overall coverage of the country for this interim period will represent a significant improvement compared to the period 1978–80.

Table 1—Sulphur dioxide: estimated emissions from fuel combustion: by type of consumer and fuel[1]

(a) By type of consumer — Million tonnes

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Percentage of total in 1982
Domestic	0.37	0.36	0.35	0.30	0.28	0.29	0.26	0.26	0.22	0.21	0.20	5
Commercial/public service[2]	0.31	0.29	0.26	0.24	0.24	0.24	0.23	0.24	0.20	0.18	0.17	4
Power stations	2.87	3.02	2.78	2.82	2.69	2.74	2.81	3.10	2.87	2.71	2.65	66
Refineries	0.26	0.29	0.30	0.26	0.28	0.27	0.29	0.29	0.28	0.22	0.21	5
Other industry[3]	1.75	1.77	1.59	1.44	1.42	1.37	1.36	1.38	1.05	0.84	0.76	19
Rail transport	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	<1
Road transport	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.04	0.05	0.05	1
All consumers	5.64	5.80	5.35	5.13	4.98	4.98	5.02	5.34	4.67	4.23	4.04	100

(b) By type of fuel

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Percentage of total in 1982
Coal	2.65	2.89	2.56	2.68	2.74	2.79	2.77	3.10	3.02	2.91	2.75	68
Solid smokeless fuel	0.18	0.17	0.16	0.15	0.13	0.13	0.13	0.13	0.10	0.10	0.10	2
Petroleum:												
Motor spirit	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.03	0.02	<1
Derv	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	1
Gas oil	0.20	0.20	0.17	0.17	0.16	0.14	0.14	0.14	0.09	0.07	0.07	2
Fuel oil	2.29	2.20	2.10	1.82	1.61	1.58	1.64	1.62	1.13	0.86	0.86	21
Refinery fuel	0.26	0.29	0.30	0.26	0.28	0.27	0.29	0.29	0.28	0.22	0.21	5
All fuels	5.64	5.80	5.35	5.13	4.98	4.98	5.02	5.34	4.67	4.23	4.04	100

[1] Excludes emissions from chemical and other processes, which probably amount to a few per cent of emissions from fuel combustion.

[2] Includes miscellaneous consumers.

[3] Excludes power stations and refineries; includes agriculture.

Table 2—Nitrogen Oxides and Hydrocarbons: estimated emissions[1] by source

Nitrogen Oxides[2] Thousand Tonnes

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Percentage of total in 1982
Domestic	51	53	53	51	50	52	52	56	52	52	51	3
Commercial and industrial	470	486	449	408	419	415	405	417	338	318	309	19
Power stations	731	808	722	760	770	793	806	876	851	818	769	46
Incineration and agricultural burning	8	8	8	10	12	12	12	12	12	12	12	1
Road vehicles												
petrol engined	262	279	272	266	279	286	303	308	316	309	318	19
diesel engined	158	170	166	162	168	171	176	182	176	167	172	10
Railways	48	50	47	44	41	42	42	41	40	39	35	2
All emissions	1,728	1,854	1,716	1,700	1,739	1,771	1,796	1,893	1,785	1,714	1,666	100

Hydrocarbons

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Percentage of total in 1982
Domestic	137	136	129	108	102	105	95	98	81	76	75	2
Gas leakage[3]	1,150	1,320	1,470	1,540	1,680	1,770	1,880	2,060	2,080	2,090	2,090	63
Commercial and industrial	16	18	19	21	22	22	21	22	20	18	19	1
Power stations	12	13	12	12	13	13	13	14	14	14	13	<1
Industrial processes	287	287	287	287	287	287	287	287	287	600	600	18
Solvent evaporation	311	311	311	311	311	311	311	311	311			
Incineration and agricultural burning	37	37	37	37	38	38	38	38	38	38	38	1
Road vehicles												
petrol engined[4]	404	430	419	410	429	441	466	475	487	476	413	13
diesel engined	35	37	36	36	37	38	39	40	39	37	38	1
Railways	13	13	12	11	11	11	11	11	11	10	9	<1
All emissions	2,401	2,602	2,732	2,773	2,929	3,035	3,161	3,355	3,366	3,358	3,294	100

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[1] The figures are based on constant emission factors and do not take into account possible changes in emission factors over the years, including changes in emission factors for road vehicles arising from progressively tighter ECE regulations.

[2] Expressed as nitrogen dioxide equivalent.

[3] Gas leakage is an estimate of losses during transmissions along the distribution system.

[4] Including evaporative emissions, which are evaporative losses from the petrol tank and carburettor.

FIG. 7

UNITED KINGDOM EMISSIONS OF SULPHUR DIOXIDE FROM 1960

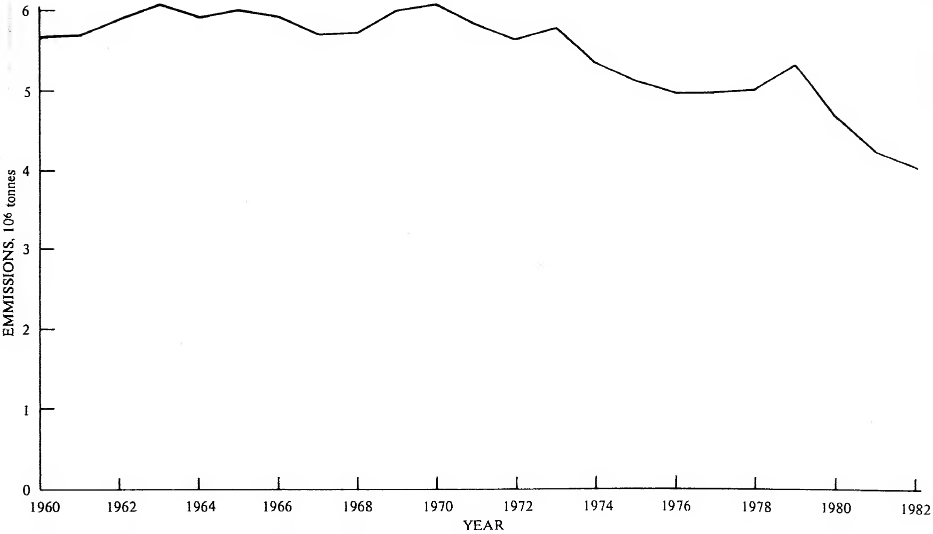
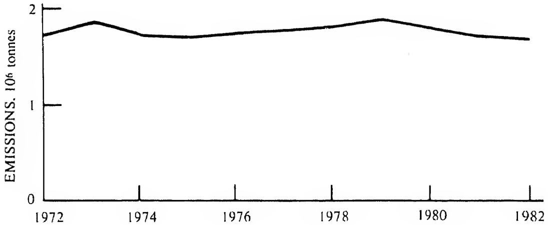
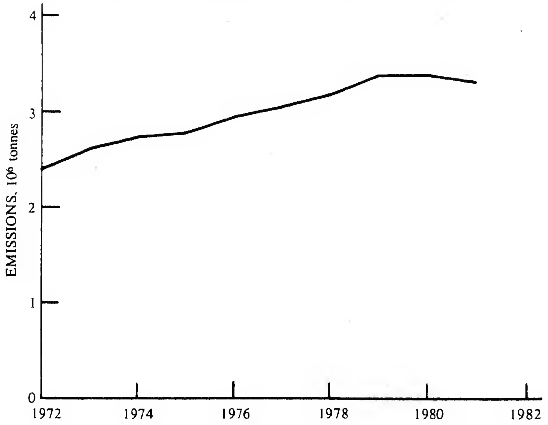


FIG. 8
UNITED KINGDOM EMISSIONS OF NITROGEN OXIDES AND TOTAL HYDROCARBONS FROM 1972

NITROGEN OXIDES (EXPRESSED AS NO_2)



TOTAL HYDROCARBONS (EXPRESSED AS CH_4)



43. Daily measurements of precipitation composition are essential to any examination of the peaks in deposition (referred to in paragraph 23), and also permit much more detailed study of meteorological and other processes than longer-term samples. Further analyses of Warren Spring Laboratory's expanding data set will continue to be carried out.

44. Warren Spring Laboratory sees it as desirable to link the above programme of work with further monitoring of oxides of nitrogen, more detailed emission data and with critical study of alternative abatement strategies.

Warren Spring Laboratory
April 1984

References

1. United Kingdom Review Group on Acid Rain (1983). Acid Deposition in the United Kingdom. Stevenage—Warren Spring Laboratory.

2. Charlson R J and Rodhe H. (1982) Factors controlling the acidity of natural rainwater. *Nature*, **295**, 683–685.

Examination of Witnesses

Dr J S S Reay, Deputy Director, Dr M L Williams, Head of Air Pollution Division, Mr S C Wallin, Air Pollution Division and Dr J G Irwin, Secretary of Acid Rain Review Group, Warren Spring Laboratory, were called in and examined.

Chairman

250. Thank you for coming this afternoon and for the documentation which you sent in advance.

(Dr *Reay.*) Our Laboratory is part of the Department of Trade and Industry researching in a wide range of areas of environmental technology and industrial process technology. Our air pollution work is largely done on contract to the Department of the Environment. The particular acid rain report which is part of the evidence we have submitted to you was in fact commissioned by the Department of the Environment. At the outset I would say, simply not to waste time, that we are not experts on the effects side; our expertise and our work to date concerns the acid deposition itself, particularly the measurement and interpretation of data on wet deposition. Members of the Select Committee will know that WSL is the principal laboratory in the UK organising and conducting air pollution monitoring, maintaining the long-term data base and modelling air pollution locally and regionally to provide Government with the technical basis for action to meet air quality standards. As a result we are thus concerned also with the strategic options, including the application of abatement technology, to meet goals.

251. That seems to confirm my reading of your report, namely that the research that you have been undertaking is primarily concerned with the monitoring of acidity levels rather than investigating causes of emissions or damage, if any, consequential upon them? Is that correct?

(Dr *Reay.*) Yes, quite.

252. How long have you been undertaking this particular research?

(Dr *Reay.*) It has had several phases. We took a full part in the OECD study of long-range transport which started in 1972–73 and although the connection had been suggested between certain phenomena such as lake acidification in Scandinavia and acid rain, quantifying acid rain and attributing the pollutants to source areas was not a simple and quick task. A lot of work had to be put in at that time in generating an adequate emission inventory of sulphur oxides and in setting up measurement stations throughout the OECD countries with acceptable quality control methods. Centrally, in Norway, the data was collated and used in modelling. We operated in the 1970s three sites continuously making daily measurements as a contribution to the OECD study and we had a further five sites which were activated during the alert periods. That study reported in 1977 and was the first to contend in a reasonably supportable fashion that acid deposition in a number of geologically sensitive areas throughout North West Europe was being caused by pollutants, a

[Chairman *Contd.*]
large proportion of which originated in other countries and could have been transported distances of 1,000 kilometres or more. It also brought out something which had not been emphasised so much before which was the role of nitrate as well as of sulphate. There followed then more work under the aegis of the United Nations Economic Commission for Europe because it was quite clear from the OECD study that we needed emission data not only from the Western European OECD countries but from Eastern Europe as well. Our laboratory has taken part again in that study.

(Dr *Irwin.*) At the present time the laboratory plays a full part in the European monitoring and evaluation programme under the auspices of the United Nations Economic Commission for Europe. We are responsible not only for the data input from the United Kingdom but play our part in the expert meetings within the programme, and the inter-comparison of analytical methods which is very important in producing a comparable data set.

253. In the course of your monitoring you say that you have identified three types of deposition which you describe as wet, dry and occult in paragraph 5. Is your research concerned at all with making any assessment as to which type of deposition may be more damaging to the environment?

(Dr *Reay.*) The answer to that question specifically is no but Dr Irwin might have something to say about the nature of the occult deposition. But on the damage side the answer must be no in relation to our research.

(Dr *Irwin.*) Very few data are available for occult deposition in the United Kingdom. The traditional precipitation collectors which we use to produce the data for the maps, for example Figure 8 of Acid Deposition in the United Kingdom, do not collect occult precipitation efficiently. Over most of the United Kingdom dry deposition is much more important than wet deposition. There is no doubt, however, that in upland areas where you have a frequent occurrence of in-cloud conditions, occult precipitation may be important. Measurements to date have been limited but they suggest that occult precipitation may equal about 20 per cent of wet deposition in these upland areas.

254. We received evidence when we were in Germany that this occult deposition, which they described to us as cloud or fog conditions amongst the trees, contained an acidity of ten times that they found normally in rain. Would that be the same as your findings or not?

(Dr *Irwin.*) We ourselves have not carried out any measurements of occult precipitation but looking at the work of others, yes when you are looking at cloud droplets the concentration of ions is much greater than in precipitation. In the formation of rain, growth and dilution of the cloud droplet has taken place so the concentrations in cloud would tend to be possibly a factor of ten greater than in wet deposition.

255. Therefore presumably if the damage effect that is observed in forests is the result of acidity in the atmosphere one would expect to find greater damage where there are cloud fog conditions prevalent rather than areas where there is more rain. Would that be correct?

(Dr *Irwin.*) We are not experts on effects but quite possibly yes, one would expect that to be the case; although occult deposition, even in the upland areas, accounts for only 20 per cent of the total wet deposition.

(Dr *Reay.*) It would depend again whether it was concentration or the total amount of acidity that was significant in terms of the effects.

256. Dry deposition is mainly local deposition. Is that correct or not? Or it is inclined to be more local than the wet or the occult. Is that right?

(Dr *Irwin.*) Yes, it would in general be more local than wet deposition.

257. Would tall stacks have much effect upon dry deposition or not?

(Dr *Williams.*) May I backtrack and partially answer the question before. If we are talking about the differences in spatial scale of dry and wet deposition, let us just say that perhaps the comparison is not a fair one to make necessarily because emissions from a particular stack will be dry deposited in a gradual sense as the pollutant plume moves down wind. Wet deposition from that same stack will depend entirely on the rainfall, naturally, and could be a very far flung phenomenon or it could be a very local one. It is determined by the rainfall. So in that sense one talks about dry deposition being more local and wet deposition not necessarily being local. In terms of tall stacks perhaps a useful rule of thumb that you might find helpful would be that if one compared the same sulphur emission from

[Chairman *Contd.*]

a very small stack and a very tall stack then the difference in dry deposition pattern averaged over the local area affected would be about 15 per cent difference: there would be 15 per cent more deposited sulphur from a small stack than from a very tall stack. So that may help.

258. The thought that was going through my mind was that we have received a great deal of evidence, certainly from abroad, about the long-range transportation of these pollutants and the argument therefore is that the United Kingdom is responsible for a lot of the acid rain and the alleged consequences of acid rain in other countries. But if dry deposition tends to fall closer to source, then we could be polluting ourselves through dry deposition and possibly our buildings which are affected to a high degree, or could be affected to a high degree by locally produced emissions. Would that be a fair statement to make or would you quarrel with it any any way?

(Dr *Reay.*) In terms of the quantity of sulphur which is transferred in dry deposition, the figure that we have, Figure 16, when you compare it in terms of quantity with the wet deposition picture shows that there is more sulphur being deposited by the dry mechanism within the UK than wet. But as originally produced sulphur dioxide is rather different from the oxidised sulphuric acid that is perhaps coming down in rain and there may be other species, including offsetting alkaline species, coming down also in the dry deposition situation. So it is not easy, not simple, simply to say that because there is more dry deposition of sulphur therefore it is doing more damage.

Chairman: In any case you have told us that you are not really researching into actual damage caused so I cannot press you further on that.

Mr Chapman

259. Warren Spring Laboratory is the research establishment of the Department of Trade and Industry, but your work is on contract in fact to any Government department, particularly the Department of the Environment.

(Dr *Reay.*) Yes; or indeed industry.

260. You mention industry and other customers. I just want to confirm that no industry, or no other customers, have asked you to do any research work on acid deposition: the National Coal Board or the Department of Energy?

(Dr *Williams.*) They have in fact. The majority of the work that we have done up to now on acid deposition has in fact been funded by the Department of the Environment as you say. The Scottish Development Department, who to some extent are the equivalent of the DOE in Scotland, are in fact funding some work with us at the moment which is relevant to the discussion we have just had on occult and standard rainfall deposition. They are funding a project where we will be looking into the effects of altitude on deposition in Scotland. They are funding that work with us currently. We would hope naturally to get some sort of handle on the occult contributions through that.

261. Reading your paper, your timescale seems to mirror exactly the international conferences there have been and the widespread concern that the Stockholm conference in 1972 presumably caused the DTI or DOE to ask you to set up the monitoring stations in 1973 and the next bulk of evidence from Scandinavia in 1977 and then the recall conference in 1982 which probably led to this publication in December 1983. I am just not quite clear in my mind. You can only do what you are asked to do but surely you can take the initiative and say you are monitoring this and you think there is a real problem and ask whether you can go back and do more research work?

(Dr *Reay.*) The programmes we conduct with DOE are partly generated by an iterative process of discussion but we cannot take the initiative if there is not a funding agency to do more work in any particular area.

Mr Alexander

262. For example you heard from the Chairman that there is some evidence that occult deposition might be ten times as intense as wet or dry. Presumably you had heard evidence of this before or heard rumours even, would you have thought it appropriate to monitor this in particular areas where fog conditions are prevalent?

(Dr *Irwin.*) Yes, we were aware of this, although it is fairly recently that there has been an upsurge of interest in the importance of occult deposition. We intend to include this as part of our study of the variation of precipitation composition with altitude which is being funded by the Scottish Development Department. It is obviously of particular interest to them as a large part of Scotland is at fairly high level.

Chairman

263. You have told us in paragraph 8 that you have just five monitoring sites in which you are monitoring the pH and sulphates and nitrates in particular. Then in paragraph 11 you speak of another ten sites in connection with the Field Studies Council where you are measuring pH. Have all those been running for the same length of time?

(Dr *Irwin.)* No. Our first site at Eskdalemuir in Scotland started in 1972–73. At that time we had two other sites as part of the OECD exercise at Pitlochry in Scotland and Cottered in Hertfordshire. At the end of the OECD exercise we continued the site at Eskdalemuir to establish a long run of data. During the period 1975 to 1977 we only measured pH at Eskdalemuir. From 1977 on we started to determine the complete chemical composition of precipitation with related measurements of sulphur dioxide and particulate species. Other sites were introduced at Goonhilly in 1979, Stoke Ferry in Norfolk in 1980, Ludlow in 1982 and Lough Navar in County Fermanagh in 1983. We intend to start a monitoring site in the South East, Barcombe Mills near Lewes, within the next few weeks and we have plans for a further site on the east coast down wind of major pollution sources which will start later this year.

264. Do you think that even then you will have a sufficient number of sites to monitor closely the local deposition of pollutants?

(Dr *Irwin.)* The question of monitoring has been addressed by the Review Group on Acid Rain as a followup to their report. We have concluded that what is necessary is to divide monitoring into two networks: a primary network, of highly instrumented sites carrying out daily measurements——

265. Are you talking of the future now and not what you have at the moment?

(Dr *Irwin.)* I am talking about the future now. The five sites I have described, plus the Field Studies Council sites are the present ones.

266. Do they have a lot of sophisticated instruments or are they rather primitive?

(Dr *Irwin.)* I would certainly regard our own five sites as highly sophisticated. The Field Studies Council sites I would certainly not describe as primitive but less sophisticated. They are using bulk precipitation collectors rather than the wet only ones which only open when it is raining. If I might look at the future now. The group concluded that for the primary network of highly sophisticated sites nine would be necessary to give an adequate coverage of the United Kingdom. The aims of this primary network would be to establish changes with time, to allow source attribution and also to allow validation of the secondary network. The primary network would run for a long time, possibly 20 years; the secondary network would consist of about 50 sites making simple measurements but run for three years, effectively to fill in the gaps which appear in the maps in acid deposition in the United Kingdom.

267. When I was in Munich a few months ago I visited what they had set up for monitoring air pollution. Throughout the Bavarian Forest they have numerous stations, all connected to Munich with a central computer. There they monitor the hourly changes of the content of the atmosphere, correlate this with wind direction and can tell very rapidly where there is going to be an unnecessarily high concentration of pollutants in any particular area. So sophisticated is this that they can stop the traffic for example in a particular area to reduce the quantity of hydrocarbons and NO_x that is going into the atmosphere. I take it that what you are saying is that we have nothing as sophisticated as that in this country?

(Dr *Irwin.)* No, at the present time we do not have anything quite as sophisticated as what you describe. We must bear in mind the aims of each particular monitoring exercise.

268. Has anybody from Warren Spring Laboratory been to Munich to look at this?

(Dr *Williams.)* Colleagues of ours have certainly seen some of the German Länders' monitoring networks, yes. Could I add a few comments broadening the question to monitoring of other species less directly concerned—concerned indirectly certainly, but not covered by Dr Irwin. It is true that the German investment in monitoring networks for gaseous pollutants—NO_x, ozone and the others—is higher than that in the UK. I believe you have already heard from the Department of the Environment as to their thoughts on the gaseous pollutants monitoring side. Perhaps I would briefly spend a moment outlining the UK position and the Warren Spring position. We operate three sites which measure

[Chairman *Contd.*]

hourly values continuously 365 days a year for NO_x at a site in central London, a site in a busy street in central London—two separate sites—and a site in Stevenage. We also monitor continuous ozone data at the central London site and the site at Stevenage and one in rural Suffolk. These are probably—and I speak from ignorance, not having seen the equipment but I suspect—providing data for these pollutants as equally sound as the German one. They represent a significant part of the UK's effort in this field of gaseous pollutant monitoring and if the Committee wished we could give a rundown of Warren Spring's activities in the broader gaseous pollutant monitoring field. Other institutions in the UK monitor NO_x and ozone, notably some universities and one or two other institutions. But it is probably fair to say that the UK overall effort in that field is not as high as the German one.

Mr Chapman

269. Are your five monitoring stations and the Field Studies Council's ten stations in the areas where there are likely to be the greatest concentrations, in other words in the line of the plume of the Midlands power stations? They do not seem to be.

(Dr *Williams.*) Could I backtrack again just a moment. If we start from the submission that Warren Spring made, the green covered document, the network outlined in the back gives a slightly distorted picture from the effort that is deployed in the whole of the UK. The next thing I refer you to would be Figure 3 in the red report, where you will see the network of stations which led to the provision of data for this report and which the results of it are based upon. There you will see the disposition of sites in the UK; a reasonable coverage in the northern half of Britain, upland Britain, a reasonably comprehensive coverage of the East Midlands region, which are primarily CEGB Midlands Region sites. There was a reasonable coverage at least of the uplands regions of Britain and of the East Midlands plume. One thing I would say is that these sites would fall into the slightly less sophisticated category in that they use bulk precipitation collectors. However, the coverage is probably reasonable in some of those areas. When Dr Irwin talked of the primary and secondary networks which Warren Spring hopes to coordinate on behalf of DOE, the primary network stations are shown on a piece of paper which I can supply to the Committee later. The secondary network sites are shown on this map which I can also provide later but you can see that there are about 100 on this map and Dr Irwin has already said that we will probably finish up with about 50. A lot of them are clustered in the same sort of area so there are lots of redundancies. Once we have ascertained that these sites conform to the strict quality assurance protocols described in the report, and we can be confident that they will provide sound data, we will incorporate these in the secondary network. As you can see, they are fairly well scattered around the uplands high wet deposition areas.

270. To laymen looking at these maps the white areas . . . I know it says insufficient data but it does give the impression that the white areas are free from the problem.

(Dr *Williams.*) As well as the black dots which represent the existing sites the review group has in fact recommended to DOE that at least 14 additional sites will be necessary to do precisely that—fill in these gaps.

Mr Alexander

271. If we just rely on Figure 1 in your evidence, the monitoring sites shown do not appear to lie in the line of the plumes from the Midlands power stations and in particular they do not include Cumbria or Galloway which are two areas which do concern this Committee. Why are they not monitored?

(Dr *Williams.*) They are not monitored by Warren Spring Laboratory, they are monitored by CEGB Midlands Region in the East Midlands area, as you can see from Figure 3 of the red report.

(Dr *Reay.*) It has perhaps been misleading in that Figure 1 shows the location of our monitoring sites; there are a large number of others from which data has been drawn, an even larger number of sites from which data will be drawn because we have been reappraising the existing sites and making recommendations for further sites which I hope will fill in those white areas on the main maps which wrongly but understandably convey the impression that there is nothing to worry about in those areas which are white.

272. So your evidence can really only properly be considered—I am not criticising; just questioning—in the light of having this red report in front of us at the same time?

(Dr *Reay.*) Yes, indeed.

Mr Smith

273. You will understand that we as a Committee are extremely concerned about the practical effects of the end product of all the scientific investigation. It just so happens that at the moment Cumbria and Galloway seem to be the two areas giving greatest cause for concern about the end effects. Looking at your Figures 3, the first specific question I want to ask is who runs the monitoring stations at Glentrool and Cairnsmore of Fleet, 18 and 19, which are the only ones operated in Galloway and which are down under the symbol marked Other?

(Dr *Irwin.*) The Fresh Water Fisheries Laboratory operates those two sites.

274. Are they what you would call sophisticated or less sophisticated?

(Dr *Irwin.*) I would regard them as secondary network sites.

275. Are you satisfied, given that the practical demonstrable possible effects of pollution are becoming evident in Galloway, that your research endeavours there are sufficient or would you want to take a closer hand in monitoring them and making them more sophisticated yourselves?

(Dr *Irwin.*) In our response to DOE, the Review Group on Acid Rain in addition to listing nine locations where they felt primary sites should be located for a long period, said we felt that two areas, one of which was Galloway, were of particular importance regarding possible effects and that monitoring to primary network standards should be conducted there, although possibly for a shorter period.

Chairman

276. Do you know if any local authorities are carrying out monitoring at all?

(Dr *Irwin.*) Yes, indeed. Several local authorities up and down the country are carrying out monitoring. We drew on information from both Grimsby and Sheffield local authorities in the red report.

277. Would these be some of the squares marked Other?

(Dr *Irwin.*) That is right, they would indeed.

278. So would your Figure 3 in the red report now be a comprehensive map of all the monitoring stations that there are?

(Dr *Irwin.*) No, it reflects the situation during the period 1978 to 1980. The map which Dr Williams held up a few moments ago shows some 150 sites where monitoring is carried out by over 20 different organisations in the United Kingdom. At present we are uncertain as to how many of these sites will meet the protocol which the review group has drawn up for monitoring. When we were writing the red report we received data from some 98 sites up and down the country. On inspecting the data, and on occasion inspecting the site, we were only able to use data from 38. This is something which we regard as very important——

279. Very unsatisfactory.

(Dr *Irwin.*) Yes.——that there should be clear protocols of measurement techniques and that the analytical performance of the various organisations should be intercompared in a series of analytical intercomparison exercises.

280. Why is there no coordination then between these monitoring stations and a correlation of information so there is somebody who forms an overall picture of the condition of air over the British Isles?

(Dr *Irwin.*) Many of the monitoring stations grew up in response to local investigations, possibly concerning effects. It is the aim that the secondary network should be centrally coordinated with strict protocols both for sampling and siting and regular inter-comparisons of analytical techniques to provide a high quality coordinated data base for the whole country.

281. Which is the lead department and who will be the Minister ultimately responsible?

(Dr *Reay.*) Department of the Environment. Mr Waldegrave will be responsible.

282. So they are taking the lead now in making sure that we have a comprehensive network of monitoring stations throughout the British Isles and that all the information obtained from those stations will be properly recorded, correlated, and

[Chairman *Contd.*]
somebody in a position to make an assessment of the evidence brought in. Is that right?

(Dr *Williams.*) Yes, that is right and that is the role the Review Group has played since 1981.

283. How far are we away, in terms of time, from seeing that set up and in operation?

(Dr *Williams.*) The primary network is well on the way to being set up and is providing data. We hope to get the majority of the secondary network sites in action and up to approved standards by 1985–86. I would hope that the majority of the primary and secondary network data that we have just talked about would be available as of 1985–86.

Mr Chapman

284. I do not want to put words into your mouth but just to confirm the position. Please disabuse me if you feel I am being unfair. Ten years after you first started monitoring, taking measurements in 1972 you prepared this red report by drawing on data from 98 stations of which you subsequently had to reject as unsound the data from 38 stations.

(Dr *Irwin.*) We used the data from 38 stations including the two Warren Spring Laboratory sites and rejected data from 60 stations.

285. That is making the point slightly greater than I intended or thought I had made it.

(Dr *Williams.*) It stresses the need for central coordination and someone to take a long hard look at the quality of the data.

Mr Chapman: You have made the point precisely.

Chairman

286. To what extent can we rely upon the graphs and the maps that you have given us? Although you say insufficient data in certain areas, and it is quite clear where that is, can you say to us that where you have shaded the maps that is absolutely accurate in local detail?

(Dr *Williams.*) No. I think it is fair to say that the question of spatial accuracy is one that could not be pushed to an extreme limit; we would not describe the contours as being accurate to the nearest 100 metres or so. The contours were drawn using a numerical method which is described in the report on the basis of the sites in Figure 3. So in spatial terms there would be a limit to the resolution that one could infer. Likewise in time resolution as well we have to mention that they are monthly samples so one could not analyse episodes of one or two days which may have led to relatively high acidity. So we have got limitations to the accuracy in both space and time of that network.

287. You mentioned in paragraphs 6 and 34 that abatement technology has also been the subject of research. Can you give us some idea of the nature of this work?

(Dr *Reay.*) One of the impressions that will undoubtedly be conveyed is that of a gap. Back in the early days of the laboratory we were in fact seriously investigating a dry technique for dealing with the sulphur emissions from power stations. But that work was wound up when the trend occurred around that time of switching from small urban power stations to large rurally located stations with suitably high stacks which dealt adequately with the particular problem of local air quality. However, we have of course kept abreast of abatement technology while not actually doing research. Mr Wallin has certainly been connected with that because it has been part of the necessary examination of alternatives in terms of strategy for reaching air quality standards. He will probably finally tell you something about plans that we currently have for further research on abatement.

(Mr *Wallin.*) As far as the past five years are concerned, we have carried out research on the fate of sulphur within combustion systems, which is important inasmuch as not all the sulphur that is in the fuel is released into the atmosphere. Therefore we have looked at a limited number of combustion systems to see the percentage that is retained in the system. Also we have carried out work on fluidised bed systems but mainly in the field: not specifically with abatement in mind but rather to get the elemental and thermal balances. Also I have been looking carefully at substitute fuels, which can account for up to five per cent of the energy requirements of the UK. The main purpose is to see what impact the combustion of these fuels has upon the environment. Most are low sulphur fuels but of course they can contribute other pollutants. I have also carried out work on the incineration of waste materials with heat recovery. In addition to SO_x it is important to look at NO_x. When we are considering abatement we need to consider this as well.

[Chairman *Contd.*]

Generally on NO_x I have been building up a base of information on the type of systems for future development for the control of NO_x, such as staged combustion, cyclone combusters and swirl combusters. Research is going on in the universities and some is planned in our own department. In addition to this I have been considering abatement systems and we have acted as consultants for exercises in industry where we have been considering the measurement of hydrocarbons that can play a part in the process. The primary aim was not acid deposition but at least it brings in data which might be relevant to this point. Currently I have submitted designs for a combustion facility at the laboratory. We have outlined proposals for plant up to about three megawatt to evaluate technologies for the control of SO_x, NO_x, hydrocarbons and other pollutants. So that is in the combustion process; but also we are going to look at the pre-combustion process as well and we have submitted plans for studying the reduction of sulphur in coal by reducing the pyritic sulphur and there are several options.

288. Is that by washing it?
(Mr *Wallin.*) That is one way but it is not very cost effective because if you wash coal then you will find that about £500 million investment is needed to reduce the sulphur by say eight per cent—I think that is the Coal Board figure. We feel that what is probably better is to consider the liberation of sulphur in the coal after pulverisation. That is one area of future work. A second area is microbial leaching. We have done a paper study on this and proposals have been prepared to carry out work there. That is in the pre-combustion area. In the post-combustion area we are intending to carry out work on the collection of sulphur by ash particles: dry processes. In addition one can then have enhancement of those processes by the addition of alkaline material. That basically is where we are working at the present time.

289. Let us assume for a moment—and it is only an assumption—that the Committee comes to a conclusion that we are emitting far too many pollutants into the atmosphere in the United Kingdom and that is having serious consequences upon the ecology both in our own country and in other countries and upon the condition of buildings. How far away are we from perfecting the technology that could economically remove the emission of these pollutants that, let us say for argument's sake, are causing the problems that are alleged of them?
(Mr *Wallin.*) I should like to divide it into SO_x and NO_x, sulphur oxides and oxides of nitrogen. As far as sulphur oxides are concerned, when we consider large users above 50 megawatts then in my view we have two possible alternatives there: the Wellman Lord system or the Mitsubishi process. One of those has had a detailed study at CEGB and the second one is under consideration.

290. Is this the pressurised fluidisation process?
(Mr *Wallin.*) No, it is not. One is the gypsum process, which is the Mitsubishi process and the Wellman Lord can also have as its output sulphur or sulphuric acid. So it is flue gas desulphurisation. Those are the candidate systems which will take about 10 years to be operational; the technology is there. As far as removal of sulphur in the fuel or reduction of sulphur in the fuel, we could be five years away from achieving that solution: maybe 30 per cent reduction is possible. But it has the advantage that if you reduce the sulphur in the fuels you do not have as long a lead time as if we were to make the decision for a 30 per cent reduction in sulphur oxides and we used those two processes of FGD that I have mentioned.

291. That is the sulphur side. And NO_x?
(Mr *Wallin.*) Also there is the post-combustion where I feel that within five years, with emphasis and some urgency, then the dry processes have got a lot to commend them and they do not require such a long lead time.
(Dr *Reay.*) There is one aspect of your question which we have not been talking about. We have been talking about technical possibilities but you said economic and we have not addressed ourselves to that. These would be very expensive to apply and whether they are worthwhile comes back to this very big and important question as to whether the sort of investment that would be involved would be commensurate with the problem that we are supposed to be addressing.

292. I was wondering whether you could indicate to us whether your researches had indicated the cheapest possible most efficient way of dealing with this problem.

[Chairman *Contd.*]

(Dr *Reay.*) No, we have not got to that point. I should like to indicate the status of the two initiatives that we have taken recently. The first of these is with our own department, with the Mechanical and Electrical Engineering Requirements Board, which is to find out what interest there would be within industry for us to have a combustion rig, the one that Mr Wallin described, at Warren Spring Laboratory up to three or five megawatts, on which it would be possible to test various abatement procedures both during combustion and after combustion. That is currently at the stage of a feasibility study with a consultant to see what interest industry has in testing out such techniques. The other initiative we have taken is to suggest to the Department of Energy, to the Coal Board, to CEGB and to our own department's requirements board that the expertise in the laboratory in mineral processing could be applied to coal desulphurisation, going beyond the traditional approach of coal washing and considering the wide range of techniques that are used in mineral work to try and remove specific species. That one has been put to the relevant committee of the Mechanical and Electrical Engineering Requirements Board which has given it a fair wind and we are about to go into detailed discussions as to what the programme should contain practically with the CEGB and the NCB.

293. You were talking about SO_x but you mentioned that you have also done work on NO_x.

(Mr *Wallin.*) Yes, I have.

294. Can you apply your answers now to that.

(Mr *Wallin.*) As far as NO_x control is concerned the big problem we have is to limit the amount of thermally produced oxides of nitrogen. This means that the temperature of combustion must be maintained below a certain limit and there are several options to do this. Those are application in fluidised bed combustion where I have looked at the effect of a fluidised bed on the evolution of NO_x and of course that is lower so that is one option. But there again, in the UK we do not have many atmospheric fluidised bed combusters. As far as staged combustion is concerned, then I have only looked critically at work that had been done in other countries. Then we have research that looks very promising for swirl combusters and also for cyclone combusters for the combustion of fossil fuels. To develop those would be a period of about five years. On the larger size combusters, the CEGB has already put a contract to NEI to consider the reduction of NO_x by dual register combustion and I think that is planned to be completed in about three years.

Mr Smith

295. In the answers that you have so far given, and certainly in the very unsatisfactory answers we got from the CEGB on what they were doing on emission control, it seems that all the emphasis has been on forms of combustion and the attempt to reduce NO_x emissions by particular forms or temperatures of combustion. Has any other work been done by yourselves or by anyone else on other possible means of reducing NO_x emissions?

(Mr *Wallin.*) Yes. In Japan there has been work done on this but in my view it is not the right way to proceed. It is quite complicated and expensive and also it has a critical window for the control of NO_x. It is quite difficult. I think there is a Shell process as well but I cannot just recall the process. You have got a pretty small window to address and I am not convinced that this is the right way to go because we can reduce NO_x from stationary sources by reducing the prompt NO.

296. What are the differences in the percentage reduction between what you envisage can be achieved by working on combustion techniques as opposed to the window principle that the Japanese are using.

(Mr *Wallin.*) If we address ourselves to the EEC directive which suggests that we have 40 per cent reduction in NO_x——

297. Forget the EEC directive.

(Mr *Wallin.*) Yes, but if we address ourselves to that then we can just achieve that by staged combustion. Fortunately in the UK, apart from one installation at a generating station, we went for dry bottom combustion which produces less NO_x than wet bottom combusters. So we have an advantage over the States and others which is something. I think we may be able to get a 40 per cent reduction by staged combustion swirl or cyclone—it may be more in new plant.

298. What can the Japanese achieve by their methods?

(Mr *Wallin.*) I need to be convinced that it can operate satisfactory.

299. What do they claim?

(Mr *Wallin.*) 90 per cent, but it is very much more expensive.

300. Granted. That we obviously have to weigh up but we need the basic facts before we can do that. In everything you have said about the research that you are doing quite a lot of what you were saying was "we are planning", "we intend to do that bit of research" and you come up with figures of five years or 10 years before you feel the technology is going to be complete. If there were greater urgency possible in your work, if you were able to speed up your research programmes, which obviously might well mean more researchers and more resources, if you were able to apply yourselves more urgently to the research on emission control technology, would that help in speeding up the achievement of available technology that could actually be used in power stations?

(Mr *Wallin.*) Yes indeed, it would help considerably. I should just like to go back one point: it is not what we are going to do, we have monitored at 100 installations and looked at SO_x and NO_x emissions so we have been active but not as active as perhaps we should have been if we were not resource limited. With more resources then we can shorten those timescales.

301. If say you were to halve the timescales that you have envisaged, how much would you require in terms of extra resources to do the work you feel you need to do?

(Mr *Wallin.*) I would need to double it.

302. Is it that simple an equation?

(Dr *Reay.*) First of all, you cannot just halve the timescale because one of the aspects undoubtedly in terms of developing and assessing technology of that sort is to see what the longer term lifetime performance is. But in addition to that, since in terms of actually working on the development of the relevant technology we are not on stream at this time I would not know what it required in absolute terms. If you want it in proportional terms then certain parts of the programmes could be halved in time if you doubled the effort but a lot of experiments in fact depend on the results of previous ones. They have got to be done serially and cannot be done in parallel.

(Mr *Wallin.*) What I would say is that I have cooperated with some of our major manufacturers at their sites and as part of our future programme it is not out of the question that we should carry out some of our work on say the manufacturers' sites. If that is done that can cut the timescale. It is rather hypothetical at the moment but we have it in mind.

Chairman

303. What troubles me a little from the evidence so far is that you keep on telling us, and we can understand this, that you need another five to ten years for research into this matter before you can really come to a conclusion or a satisfactory solution. Yet we are told that the Germans are so well advanced that by 1988 they hope to have reduced the NO_x emissions by 40 per cent which seems to argue that they have carried out all their research into the causes of emissions, the results and also the technology for reduction of these emissions. Why is it they can be doing this and we still need another five or ten years and why can we not borrow from them?

(Mr *Wallin.*) Some of the German processes that I have looked at have got some limitations to them. It is what they claim and not actually what they achieve. Also, if it comes to NO_x then our plant works very well with minimum oxygen demand but if you take the German situation then a lot of these generating stations were put in at the end of the war and they are coming to the end of their life. If you take the UK however, we have installed many of our larger stations over the last ten years—in fact some are just coming on stream now. Those are better designs and they have better air control. Air control, or oxygen demand, is very important for NO_x control so ours probably perform much better than the comparable German ones do at the present time.

304. But we are still second in the league of production of emissions are we not for these pollutants in Western Europe?

(Dr *Reay.*) I do not know where we are on NO_x; in terms of sulphur emissions, which relates obviously to the fuels we use,

[Chairman *Contd.*]

that sort of order is correct but I do not know where we lie in terms of NO_x emissions. What Mr Wallin is saying is that the situation in Germany and the UK is quite different in terms of the age of plant and whether in fact it is up for renewal.

305. They are still talking of retrofit you know, they are not talking of construction of new power stations; they are talking of retrofit of burners and boilers and all sorts of things and they seem to say that they have the technology to do this.

(Dr *Reay.*) Mr Wallin in fact said that there was the available technology. Whether it is economic is another matter but there was the technology with the Mitsubishi process, the Wellman Lord process for SO_x and that you could do a number of things with burners for NO_x.

(Mr *Wallin.*) But the Limestone Injection Multistage Burner (LIMB) process that the Germans are putting great emphasis on still has problems with the particular design. This is a personal view but I am not convinced that that is the right way to go. I feel that other methods for control are preferable.

Mr Chapman

306. You mentioned the Japanese but added at the end that it was much more costly. Can you be more precise?

(Mr *Wallin.*) Yes, I think I can but I will have to draw it out. A 40 per cent reduction in NO_x say, will involve no increased operating costs with a multi-stage burner and for a 2,000 megawatt set it will cost something like about £1 million. There again it is not terribly expensive compared with FGD for SO_2, whereas if you take say the Japanese process which is frightfully complicated——

307. And they claim 90 per cent?

(Mr *Wallin.*) Yes, but then there are increased operating costs and I would submit that to you but I cannot pull that out in a moment. It would be something like about £15 million per year operating costs whereas a low NO_x burner would not increase our operating costs appreciably. So those are the good reasons why we should go that way with caution.

Mr Smith

308. You said £15 million. Is that an annual extra operating cost that you are envisaging with the Japanese process?

(Mr *Wallin.*) Yes.

309. Do you have any figures on the capital cost of installing the process?

(Mr *Wallin.*) Yes. If you will bear with me one minute I will look them up.

310. The equivalent production of 2,000 megawatts that you were talking about for the combustion process.

(Mr *Wallin.*) We would have to be a little bit careful here because we have costs in mls/kilowatt hour and I would prefer to put this in separately as a submission so that I can give you the relevant costs. They are considerably higher.

311. If we could have that I think it would be extremely useful, with an exact comparison between the Japanese method and the combustion methods. Obviously we have to weigh up what recommendations we are going to make in terms of reduction and in terms of cost and if we do not have the basic information to compare various systems we cannot make a decision.

(Mr *Wallin.*) I would add that of course there is an unknown because a lot of these systems are not working at the moment and with the complication then there may be very high maintenance costs. I will give you the minimum operating costs but they could be much higher.

Chairman

312. You just gave us a figure a moment ago of £1 million for 1,000 megawatts.

(Mr *Wallin.*) For 2,000 megawatts.

313. The CEGB have told us that it would cost them about £2 million for 660 megawatts.

(Mr *Wallin.*) It depends how they submit this because if you can introduce the burners when there is annual maintenance then that reduces the cost so that it will depend upon the way that they are planned for installation. If it is something where they shut the plant down specifically for this and do not integrate it with their planned maintenance system then it increases the cost of installing the burners enormously.

314. I would have thought that anybody in their right senses would have looked at a point in time when they can do it the cheapest. Why give us conflicting figures in this way.

[Chairman *Contd.*]

(Mr *Wallin.*) My information comes from the CEGB on those costs and their preferred methods.

315. Thank you. We will possibly have to take this up again with them. Am I right in assuming from what you said earlier that you cannot offer us any evidence at all on damage, the effect of acid depositions on buildings for example and corrosion of metal?

(Mr *Wallin.*) No. The only corrosion work I have done is within the system itself.

316. There does seem to emerge from your paper a difference in the levels of acidity between urban and rural areas but you do say that your information about acidity in urban areas is somewhat sparse. Do you intend to intensify your collection of data from urban areas?

(Dr *Irwin.*) Indeed, information on acidity in urban areas in the United Kingdom is very sparse. There are particular problems in monitoring acid deposition, wet deposition, in urban areas in that at rural sites we specifically choose locations to be remote from local sources of pollution which would contaminate or affect the results. In an urban area of course you are surrounded by a multitude of such sources. What one would aim to do would be to establish the range of variability of acidity within urban areas. We have given some thought as to how this type of experiment might be conducted, although we have no immediate plans to do so.

317. One of the matters that has been concerning us is the effect of acidity upon buildings and the corrosive effect on various kinds of building materials. We have received evidence that indicates there is a correlation between the degree of acidity and the amount of corrosion that takes place. Other evidence has indicated to us that corrosion of buildings takes place due to a multiplicity of causes: frost was given as one reason and I can understand that. Therefore, in the absence of more positive evidence that we have at the moment of the degree of acidity in urban situations it is hard for us to reach conclusions as to the effects upon buildings and building materials.

(Dr *Williams.*) If we are talking about the effects on building materials and the fact that the majority of these are found in urban areas almost by definition means that they are exposed to a variety of pollutants, not least of which may be the gaseous ones that we talked about earlier. What we did not talk about earlier was the gaseous pollutant monitoring for smoke and sulphur dioxide, gaseous sulphur dioxide which Warren Spring coordinated for the last 20 years or so in the UK. The majority of sites are in urban areas so we have got a reasonably good picture of SO_2 concentration distribution in urban areas. While the proportions of contribution are still unknown, it is quite likely that the dry deposition of gaseous SO_2 could well be a major factor in such corrosion. In fact our role in this is as provider of SO_2 concentration patterns in urban areas in the UK. We have indeed collaborated with the Building Research Establishment in this activity. As Dr Irwin says, our knowledge of deposited acidity in urban areas is limited.

(Dr *Reay.*) Coming back to the point we made earlier about dry deposition, it is quite possible—and this is only hypothesising—that the impact of gaseous sulphur dioxide and other pollutants on to wet stone is more important than the acidity of rain falling on that stone.

318. You have also mentioned to us that much of the deposition is episodic, in other words a large part of the annual total falls upon very few days in every year. What is the scientific explanation for that? Why should that happen?

(Dr *Irwin.*) This is a particularly interesting observation. First of all it is probably worthwhile pointing out that rainfall itself is highly episodic, but whereas we might find 30 per cent of the total rainfall occurring perhaps on 10 per cent of the wet days of the year, we will find 30 per cent of the acidity deposited on three or four per cent of the wet days. We have had a look at the episodicity at a site we have in East Anglia where we found that in 1980 30 per cent of the sulphate deposition occurred on just five days. We looked at the back trajectories of the air masses giving rise to those high deposition episodes and we found that these were slow moving air masses that had drifted in from major source areas, both in the south east of the United Kingdom and continental Europe. It is an interesting observation that, at least in the south east of England the episodes could well be related to sources in continental Europe. So, whereas the bulk of the deposition arrives on a westerly air stream, you do find situations where a stagnating anticyclone over a major source area moves on and heavily polluted air is drawn

[Chairman *Contd.*]
into an active frontal system resulting in a high deposition. This is interesting in the Scandinavian context as well. Whereas in Scandinavia you find that the bulk of the sulphate deposition arrives on westerly or south westerly air streams for the episodes of highest deposition, the meteorology is different and they tend to be associated with easterly or south easterly airstreams coming from among others the German Federal Republic or the German Democratic Republic. So the meteorology for episodes can be somewhat different from the overall situation.

319. That is very interesting because the Swedes tend to blame us for a lot of their problems and it would be interesting if we could produce evidence to show that it comes from the east and not from the west.

(Dr *Reay.*) That is episodes as against just natural times.

320. That is very interesting because we have received evidence in so far as damage is concerned that the sudden fish kills occur after an episode and not when the acidity attains a constant level.

(Dr *Irwin.*) There certainly has been work done at the Metereological Office which has shown the weather patterns giving rise to episodes in Scandinavia.

(Dr *Reay.*) We are supplying bits of a jigsaw. As I said at the beginning, we know nothing about effects, but one of the main reasons obviously for having daily measurements as we do, is that when these episodes occur, having that sort of time resolution in the totality of quality of the rain and the amount of the rain, you can then begin to do the backtracking of the trajectories and find out where that air mass came from. We are providing that sort of data.

321. So it is this stagnant air flow which is the cause of two observations you make in your report: first the highest degree of acidity is in the south east of the country and secondly, that it is responsible for the high episodes?

(Dr *Irwin.*) Could I deal with the second point. That is certainly one of the situations which we have identified as giving rise to episodes of high deposition. Another one is when it is simply not particularly polluted air but a very large amount of rainfall which can give rise to an episode. For the south east of the United Kingdom, yes episodes play a part but it is more than episodes, it is the location of the south east of the United Kingdom with respect to the major source areas in Europe as well as the United Kingdom. Our maps in the red report do not show Europe and really in the south east of the United Kingdom we are quite close to major source areas on the continent.

322. So it would be an advantage to the south east of the country if we could reach agreement with our neighbours for the European reduction of emissions?

(Dr *Irwin.*) It is fair to say that overall 80 per cent of the sulphur deposits in the United Kingdom arise from United Kingdom sources, the overall contribution from other countries is small, but it is probably most pronounced in the south east.

323. May I thank you all for coming and giving us your help this afternoon.

(Dr *Reay.*) We will let you have the information that we promised.

324. Is there anything that occurs to you as a result of our questioning and our discussions that you feel you ought to say to us before you leave? Are there any concluding remarks that you feel would enlighten us where you feel we need enlightenment?

(Dr *Irwin.*) May I make one comment. We have spoken of the 1978–80 situation. We have spoken of our plans for future monitoring. It is probably worthwhile pointing out that in the meantime the Review Group intend to update this report to the period 1981–83. Different sites were in operation during that period, some sites ceased to operate and new ones were introduced. So we may have a slightly different coverage of the United Kingdom for that period. It is unlikely to represent any great improvement but there will be data available in the interim period and we do not have to wait until the secondary network has been in operation for a couple of years.

Chairman: May I thank you again for coming here this afternoon.

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MONDAY 18 JUNE 1984

Members present:

Sir Hugh Rossi, in the Chair

Mr Richard Alexander
Mr Sydney Chapman
Sir Reginald Eyre
Mr Allan Roberts
Mr Chris Smith
Mr John M. Taylor

Memorandum submitted by the Society of Motor Manufacturers and Traders Limited

ACID RAIN

Emissions Involved in Acid Deposition

The two main pollutants involved in acid deposition are sulphur dioxide (SO_2) and oxides of nitrogen (NO_x). The emission of SO_2 from vehicles is negligible and therefore is not considered further in the following discussion. The emission of NO_x from motor vehicles accounts for about one quarter of the total man-made emissions of NO_x in the United Kingdom.[1] As the total NO_x emissions account for approximately 30 per cent of the acidity[2] the motor vehicle contribution to acid deposition represents 7.5 per cent of man-made emissions.

Environmental Effects

There is some uncertainty at the part played by NO_x in acid deposition.[3] Much of the chemistry relevant to acid deposition is not well understood. It is generally accepted that a major pathway to the formation of nitric acid is through oxidation of nitric oxide (NO) in two steps, first to nitrogen dioxide (NO_2) and then to the acid (HNO_3). These reactions are intimately connected with the chemistry of smog formation, and involve other atmospheric species, including hydrocarbons and ozone.

There is also an interaction with the process whereby sulphur dioxide is converted to sulphuric acid. Laboratory studies suggest that the oxidation can take place in the gas phase, in droplets, and on surfaces. A predominant reaction in the gas phase is that of sulphur dioxide with the very reactive species known as the hydroxyl radical, OH. But this is the cause of a further complication; it is known that OH also reacts with NO_2, and it does so at a rate that is ten times faster than the reaction with SO_2. This means that the two pollutant gases compete with each other for the available OH, and would lead us to predict, for example, that nitric acid formation occurs closer to the source than sulphuric acid formation. Actual measurements have confirmed this prediction, allowing us to conclude that decreasing NO_2 will result in the sulphuric acid being deposited closer to its source in place of nitric acid.[4,5]

One further aspect of the relevant chemistry can be mentioned; this relates to the acidifying effects the various deposited species have on the ecosystem. For sulphur, the three major deposited species, sulphur dioxide, sulphuric acid and ammonium sulphate, all are expected to cause ultimate acidification of aquatic and terrestrial ecosystems. However, little net acidification results from deposition of nitric acid.

Nitric acid can be thought of as being made up of the hydrogen ion H^+, and the nitrate ion, NO_3^-; $HNO_3 = H^+ + NO_3^-$. Unlike sulphate, most of the nitrate deposited does not cause acidification, due to its rapid biological utilization by plants. This latter process

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takes place with release to the soil of a hydroxyl ion, OH^-, so that the plant can retain its electrical neutrality. As a result, for each NO_3^- taken up by a plant, an OH^- is released to the soil to react with a H^+ and form a neutral molecule of water, H_2O.

Monitoring studies in actual ecosystems have demonstrated that most of the nitrate is, in fact, utilized by plant life in the ecosystem—while most of the sulphate passes through unused.[6]

Setting Emission Control Standards

The Society is involved in discussions relative to the vehicle emission control requirements both within the Common Market (EEC) and within the European Economic Commission of the United Nations (ECE). Until recently the lead has been taken by ECE who have developed Regulation 15 for passenger cars, to the point of the fourth amendment 15-04, also Regulation 49 for diesel engines. Within the ECE proposals are first considered by the GRPE which deals with pollution and energy. Any proposals by this Group are then considered by the Group of Experts on the Construction of Vehicle (WP29). Industry is represented on both these Groups in an advisory capacity. HM Government is represented on both these Groups.

Within EEC a working group was formed, known as ERGA I (Evolution of Regulations—Global Approach) which produced a report in August 1983.[7] The UK motor industry—through CLCA, CCMC and CLEPA—have been directly involved in this work, and officials in the Department of Transport have consulted SMMT fully at every stage. At least partly as a result of this close co-operation between those responsible for the study and experts in the various technical fields involved, the UK motor industry is in a position wholeheartedly to endorse both the approach adopted in the study and the analysis contained in the report. In particular, we wish to single out for commendation the following:—

(a) the emphasis placed on the relationship between vehicle emissions and air quality, and the prime importance of air quality standards in assessing the health and environmental effects of motor vehicle pollutants;

(b) the technico-economic analysis of technologies which could be used for the reduction of pollutant emissions from motor vehicles—the subject of Item 2 in the report; this contains on pages 60–64 a well-balanced assessment of different technology system;

(c) the extremely valuable contribution made by Department of Transport officials both to the approach adopted in the study and to the development of the analysis contained in the report.

As a result of this report, proposals are to be made by the Commission to the Council of Environmental Ministers for their consideration, following which the Commission will be charged with formulating the necessary legal documents. Study of these will be made by the "Motor Vehicles Group" on which the motor industry serves in an advisory position.

Emission Reduction Technology

Various methods of reduction of emissions from petrol engined vehicles have been considered and are discussed in detail in the ERGA I report referred to above. Also covered are costs and fuel consumption changes.

For diesel engined vehicles the technology available to reduce emissions is not well documentated, possible because NO_x levels are lower than petrol emissions, however it is known that the use of catalysts to control emissions of NO_x from diesel engines is not possible due to the high concentration of oxygen in the exhaust.

Conclusions

1. The subject of acid rain is not well understood. There has not been sufficient research into the subject as is evidenced by the conflicting statements in the published literature.

2. From the limited information in the published literature the conclusion is that although motor vehicles do emit pollutants they are not major contributors to the problem; it may well be shown that their contribution is very small.

3. The continued developments to engines to improve combustion systems and in consequence very much reduced use of fossil fuel to carry the same amount of passengers and goods will diminish the contribution by vehicles.

4. Further reductions in NO_x would require consideration of vehicle on costs, fuel *consumption increase* penalties and in-use performance. The latter could be important since a technology that produces extremely low emissions on a type test basis but deteriorates significantly in service may be a poorer option to adopt than one which maintains an initially more modest emission performance throughout its working life.

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27 April 1983

Memorandum from BL Technology Ltd

In reply to your letter of 23 March, addressed to Sir Austin Bide, requesting evidence on the subject of Acid Rain, we must first state the definition of this phenomenon used as a basis in this response.

We understand Acid Rain to be a form of atmospheric pollution created by rain precipitation containing dissolved acidic materials. These acids are primarily sulphuric and nitric acids, and are believed to be transported by weather conditions over long distances across national borders in addition to being deposited locally.

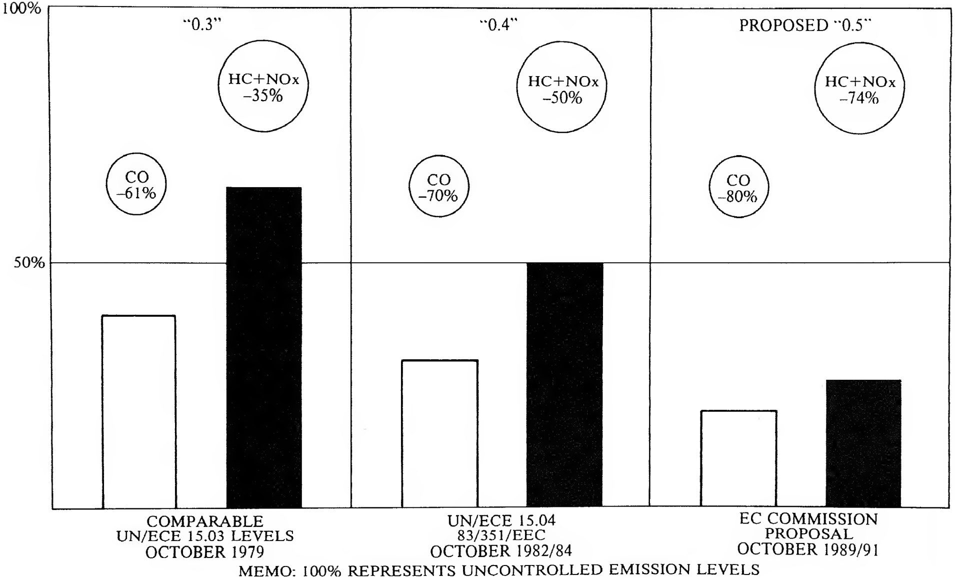
Although we have not been directly involved in research into the formation and transport of these acids or their effects, we are concerned with protection of the environment and have conducted many literature reviews in order to study the possible role of transport in this connection.

A list of the principal sources used in this study is attached as Appendix 1 to this letter.

In addition to these reviews, we participated in the Royal Society meeting held in September and have held several discussions with personnel from the Warren Spring Government Laboratory in order to keep ourselves informed.

Our main conclusion is that automotive sources are not major contributors to the formation of Acid Rain. We believe that the acidic components of the rain appear as 70

COMPARATIVE EMISSION LEVEL REDUCTIONS



per cent sulphuric and 30 per cent nitric, these being formed as a result of atmospheric oxidation of Sulphur Dioxide and Oxides of Nitrogen combining with water vapour.

Our opinion on the relationship between vehicle exhaust emissions and Sulphur Dioxide is contained in Appendix 2 and Oxides of Nitrogen in Appendix 3.

Based on the information derived from our literature review, we estimate that road vehicle sources account for a minute amount of the Sulphur Dioxide emissions and a small proportion of the Oxides of Nitrogen emissions, when taking into account both naturally occurring and combustion sources in Europe.

It would appear that the major sources of Acid Rain material are stationary fossil fuel burning sources, and we anticipate that the £5M research project sponsored by the National Coal Board and the Central Electricity Generating Board announced by the Royal Society in September will confirm this view.

We welcome the establishment of this programme, and hope that it will provide answers to the important questions raised in your letter.

For our part, we should make you aware that BL PLC is working with several European vehicle manufacturers acting through the CCMC (Committee of Common Market Automobile Constructors) to make significant research into the study of automotive emissions and the impact they may have upon the environment. These programmes have included mathematical modelling of the environment in the City of Turin in order to study the distribution of motor vehicle emissions at various legislative limits, and have included a study of long and short term biological effects together with a study of the lean burn combustion approach to the limitation of vehicle emissions.

We have also been an active contributor to the Evolution of Regulations—Global Approach (ERGA) Studies held under the auspices of the European Commission in Brussels. These studies resulted in reports labelled ERGA I and ERGA II containing information on vehicle emission control, cost effect and impact on the environment.

We support this global approach concept, and recommend study of these reports by your Committee. Copies are held by the various Ministries—Transport, Industry, Environment and Energy.

Our studies to date lead us to believe that there is no clear evidence providing justification for more stringent passenger vehicle emission control legislation over and above the pending ECE 15/04 levels or for heavy duty diesel vehicles beyond the proposed ECE Regulation 49. Any premature movement beyond these levels would cause significant loss in fuel economy and possibly create other adverse economic consequences.

In conclusion, it is our view that there is considerable difference of opinion within the Scientific Community regarding the link between Acid Rain and the reported damage to forests and lakes. The contribution of automotive vehicles is not a major source and it is possible that changes in legislation to control apparent sources of pollution may well lead to adverse overall effects. We believe that considerably more knowledge is necessary before one is able to make valid judgements on the mechanisms involved and their effects.

H Sheron
Chairman and Managing Director
BL Technology Limited

30 April 1984

APPENDIX 1

Literature References

Following a review of over one hundred references, we consider those listed below as the most informative:—

1. Royal Commission on Environmental Pollution—Tenth Report. February 1984 HMSO Cmnd 9149 ref ISBN 0 10 191490 3.
2. Acid Rain—A review of the phenomenon in the EEC and Europe. Environmental Resources Limited. Published by Graham and Trotman for the Commission of the European Communities. 1983 ref ISBN 0 86010 5016.
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5. Acid Deposition and Motor Vehicles USA MVMA May 1983. Available from BPICA. 4 Rue de Berri Paris. Communication 28 Nov. 1983. ref T-21003 J6P/LB.

APPENDIX 2

Relationship between Motor Vehicle Exhaust Emissions and Sulphur Oxides

The relatively small quantities of Sulphur Oxides emitted from motor vehicle exhausts are directly related to the sulphur contents of the fuels used, since a high proportion of the in-going Sulphur is emitted directly from the tail pipe as Sulphur Dioxide with a smaller quantity being retained in the engine system as sulphate deposits. Calculations based on typical Sulphur content of petrol and diesel fuels, and the annual consumption of fuel, indicate that vehicles contribute approximately one per cent of the total Sulphur Dioxide emissions in the UK. It is evident, therefore, that any emission control strategy resulting in deterioration in fuel economy will increase total fuel used and therefore the quantity of Sulphur Dioxide emitted from exhausts. This leads us to the view that the adoption of low octane fuels or the more elaborate emission control techniques based on catalysts would be a retrograde step.

We do not know of any currently viable control technology that could be applied to vehicles to control Sulphur Dioxide. A possible approach would be the hydrodesulphurisation of fuels by the Petroleum Industry, but this is known to involve significant cost penalties.

APPENDIX 3

Relationship between Motor Vehicle Exhaust Emissions and Oxides of Nitrogen

The formation of Oxides of Nitrogen in motor vehicle exhaust emissions is affected directly by the pressure and temperature of combustion. In addition their concentration is influenced by the ratio of fuel to air entering the combustion chamber, the compression ratio, the engine speed and the operating conditions of the vehicle. The emissions may increase or decrease, depending upon the ratio of fuel to air relative to the stoichiometric or ideal chemical mixture ratio. Emissions will increase to a maximum on the lean side of the stoichiometric mixture, and will rapidly decrease in what is known as the lean burn engine. It is with this effect in mind that we advocate the lean burn approach to emission control, since this will maximise fuel economy and should lead to lower emissions of Oxides of Nitrogen for petrol fuelled engines.

In the case of diesel engines, the control technology is not so advanced as petrol engines, and current knowledge suggests that reduction can only be achieved by changes to the rate of fuel injection or the compression ratio, and each of these may in turn lead to losses in fuel economy and deterioration in the vehicle performance.

We know that Ozone is necessary for the rapid oxidation of Oxides of Nitrogen and Sulphur Dioxide, and one of the sources of Ozone is the photochemical reaction between reactive Hydrocarbons and Oxides of Nitrogen. Since increases in atmospheric Ozone are not desirable, we believe that careful research of the sources of its generation are required.

Memorandum from the Ford Motor Company Limited

Thank you for the invitation to assist the Environment Committee's Inquiry into Acid Rain.

You will, of course, have access to reports from expert bodies such as Warren Spring Laboratory on the nature of the acid rain concern in the UK. I will therefore confine my comments to points (iii) and (iv) of your letter of 23 March.

The exact contribution of motor vehicle exhaust gases to acid rain is acknowledged by competent analysts to be uncertain, but all agree that it is a small part of the total; the overwhelming majority source is sulphur dioxide from electricity generation and heavy industry. Ford is concerned with the contribution of the motor vehicle to the extent that the various constituents of exhaust gases, particularly oxides of nitrogen, are believed to be important.

Progressive reductions in exhaust emission limits since the early 1970's require today's cars to meet standards for carbon monoxide which are 70 per cent lower, and for hydrocarbons and oxides of nitrogen combined some 50 per cent lower, than the original 1969–70 standards.

Research within Ford on combustion processes in gasoline engines is leading to engine design technology that promises further significant reductions of emissions of oxides of nitrogen; reductions of about 50 per cent compared with today's engines appear feasible without increased emissions of other equally undesirable exhaust components, whilst at the same time offering much improved fuel consumption.

Sam Toy
Chairman and Managing Director
Ford Motor Company Ltd

2 May 1984

ACID RAIN

IS THERE AN AUTOMOBILE CONTRIBUTION?

Ford Motor Company Ltd,
Research and Engineering Centre,

June, 1984

GENERAL

There is considerable concern in Europe in regard to the observed damage to plant life, particularly in the Black Forest, and to the loss of aquatic life in streams and lakes over most of the northern part of Europe.

Acid rain has been blamed for this effect and until now the phenomenon has been laid at the door of sulphur dioxide (SO_2) and generally related to the emanations from electrical generating stations and similar heavy industry.

Recent suggestions have been made that oxides of nitrogen (NO_x) which can derive naturally and from both internal and external combustion devices may also be causing damage to plant life possibly direct or as a precursor to the formation of nitric acid (HNO_3) and ozone (O_3).

However, the theory of NO_x damage remains a theory rather than a proven fact. Indeed it is not fully established that plant damage is caused by acid rain at all and certainly the damage capability of the constituents of acid rain has not been properly quantified.

OBSERVED CONDITIONS

NO_x itself may not damage plants although it is believed to have a synergistic effect in heightening the damage potential of other individual pollutants; the mechanism of this process is not well understood.

What is more certain is that the derivatives of NO_x, that is nitric acid (HNO_3) and ozone (O_3) when found in significant quantities do have a deleterious effect on plant life.

The NO_x derivatives are rather persistent commodities and therefore their removal time from the atmosphere to the soil, including time for the change from the gas (NO_x) to acids (HNO_3 and O_3) is likely to be lengthy and possibly spread over some few hundreds of miles.

In rain conditions this change and deposition time will be considerably less so that the normal climatic conditions of individual territories can affect the deposition band width of the acid derivatives.

Thus if automobile NO_x is a cause of plant damage it should by now be possible to detect signs of such damage on the side of a motorway, opposite to that of the prevailing wind, stretching out for quite a long distance from the road itself.

No such observation has been reported.

AUTOMOBILE CONTRIBUTION

If for the sake of argument the passenter car is considered a contributor to acid rain it is inevitable that NO_x would be the main agent. Of the total gases emitted from the exhaust of the average car the acid pollutant precursors form about 0.02 per cent, and of this small percentage only 5 per cent are sulphur based while the nitrogen based gases account for 95 per cent, that is 0.019 per cent of the total.

Indeed when the content of NO_x from the vehicle is compared to that derived from other sources it does not assume a very significant proportion. The total United Kingdom NO_x inventory, (ie the theoretical emission from all sources, plant decay, power stations etc) accounts for about 30 per cent of acid rain while the automotive contribution to this NO_x total is about 23 per cent.

It therefore follows that the automotive contribution to acid rain is:—

$$30\% \times 23\% = 7\%$$

If we add the contribution from diesel road vehicles then this figure rises to 9 per cent with a scatter of perhaps + or −2 per cent due to possible errors in the emission inventories.

AUTOMOBILE NO_x REDUCTION

Assuming once again for the sake of argument that it is worthwhile to reduce automobile NO_x, how may this best be done?

To reduce NO_x from power stations a number of solutions are available all of course with penalties provided along with the benefits, not the least being the cost of such solutions. To reduce NO_x in the automotive world there are also several methods but again they each have their individual penalties.

(1) *Retard ignition advance*

Not a very effective method since the retardation has to be massive to reduce the NO_x emissions significantly. Drive quality will suffer badly and so will fuel economy, the latter worsening in the order of four to seven per cent.

(2) *Exhaust gas recirculation (EGR)*

This is perhaps the most effective method and technology exists to carry out such schemes. Drive quality does worsen slightly but if a fairly sophisticated control valve is used (possibly electronically modulated) then for most customers it will not be detectable.

Fuel economy will also worsen slightly but probably in the order of two to three per cent which might be considered an acceptable penalty.

What will worsen is the carbon monoxide (CO) emissions which may degrade by 10 or more per cent. Some of this might be recoverable by applying engine management systems but this relatively modest depreciation must be regarded as the penalty for the benefit of reduced NO_x when using this approach.

A further point is the possibility of the EGH system passages plugging up with combustion products. To keep the system working efficiently the passages would need to be cleaned out during the vehicle regular service period, say every 12,000 miles or once a year.

(3) *Lean Burn Engines*

A lean burn engine can be defined as a gasoline engine where the air fuel ratio is greater than 18:1. With such air fuel ratios the NO_x emission are on a downward trend and thus move towards a self regulating situation; economy improvements of up to 15% are forecast as an added bonus.

Such engines are in a high state of development and it is expected that they will commence production within the next two or three years.

(4) *Catalysts*

This type of exhaust gas after treatment can reduce NO_x without either carbon monoxide or drive penalty and as such is a very useful tool. Unfortunately as catalysts contain "noble" metals such as platinum and rhodium they are also expensive. It should be kept in mind that catalysts can only successfully run on non-leaded fuel, they quickly cease to operate if leaded fuel is used in the vehicle. Therefore if catalysts are to remain an effective control there is a concern about the quality of the fuel (eg lead (Pb) contaminant) and they could need replacing at some advanced mileage at considerable cost to the owner.

Perhaps of more immediate concern is the requirement that for a catalyst to operate correctly the engine fuelling must be carefully controlled to a level much richer than today's vehicles. Thus the fuel economy will worsen between five and 10 per cent compared to 1984 vehicles which would be a severe penalty both nationally and to the individual owner.

(5) *Control Conclusions*

In effect the best immediately available solution in terms of fuel economy, cost and hardware is the exhaust gas recirculation route with possibly a small "let" given on the allowable quantity of CO emission.

Slightly longer term the lean burn engines will be ready to reduce the NO_x output without any other emission penalty and with the potential to further improve on today's fuel economy.

SUBMISSION BY FORD MOTOR COMPANY LIMITED TO THE ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION ON THE SUBJECT OF AUTOMOBILE EXHAUST EMISSIONS

Ford Motor Company Limited

August 1983

These notes are intended to highlight aspects of various technologies which could be adopted, either through legislation or voluntarily, by the automobile manufacturers for the control of automobile exhaust emissions.

Her Majesty's Government having announced its acceptance of the Royal Commission's recommendation to introduce gasoline without lead into the United Kingdom, there is now a possibility of using a "Catalyst" for the control of exhaust emissions. Before such a step can be discussed a clear understanding of the technical requirements is necessary. Similarly, an understanding of the New Alternative Technology to the Catalyst is needed—its advantages/disadvantages, costs, possibilities and requirements.

The statement is in four parts:—

—Catalyst Technology
—The New Technology (the Lean-Burn Engine)
—The Lifetime Concept
—Conclusions
    Plus a Glossary of terms

CATALYST TECHNOLOGY

Ford, in the United States, has over ten years of experience with catalytic converter exhaust systems, and builds some two million vehicles or more each year, fitted with these devices.

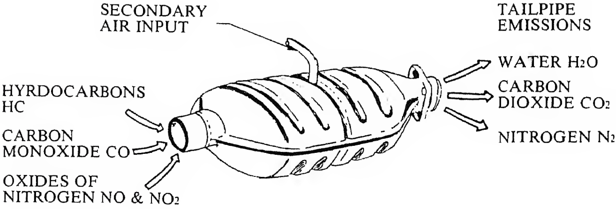
The technique has the capability to reduce the amount of exhaust gas emittants to extremely low levels. However, in order to provide "lifetime capability" to a vehicle equipped with catalysts, great care in driving techniques, inspection and maintenance are required. Furthermore Government must accept that, in the real world, there will be considerable periods of time when the exhaust emissions from catalyst equipped care are effectively untreated, due to traffic and other operating conditions.

Catalysts used in the United States and proposed by some sources for Europe are of two types, the Reducing catalyst, known as a "Three Way" (TWC), for the control of Nitrogen Oxides (NO_x) partial control of Carbon Monoxide (CO) and Hydrocarbons (HC) and the Oxidation catalyst for the control of CO and HC. Both are comprised of washcoats of noble metals (platinum, palladium and rhodium) on a ceramic honeycomb substrate base. The principal sources of these noble metals are the USSR and South Africa. They require "lead-free" (not "unleaded") gasoline for their successful operation. Figure 1 shows a typical "twin" arrangement of a TWC and an oxidation catalyst from a US Ford produced vehicle.

In order to operate a catalytic converter system for the current US law, a very complex and expensive arrangement is required. Figure 2 shows this in diagrammatic form. Many "hang-on" items are needed, for the supply of "secondary air", for "exhaust gas recirculation" (EGR), for ignition control, etc. All are normally controlled electronically. Figure 3 shows more details.

Catalysts operate most efficiently at exhaust gas temperatures between 600 and 800 Centigrade. They require a minimum exhaust temperature to "light up" (ie: "start to operate") of around 300 C, and are limited to a maximum exhaust gas temperature of about 900 C.

FIG. 1
TYPICAL "TWIN" CATALYST



PRINCIPLES OF CONSTRUCTION

ASSEMBLY

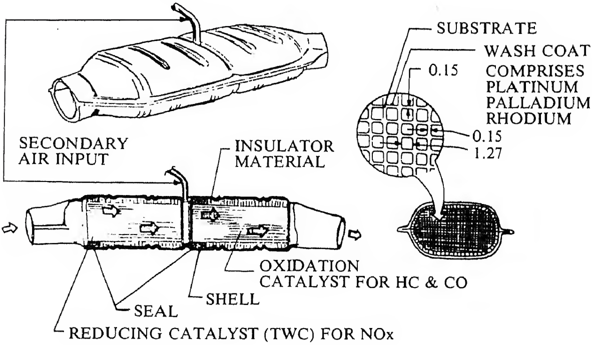


FIG. 2

TYPICAL EXHAUST EMISSION CONTROL SYSTEM TO MEET CURRENT U.S. FEDERAL EMISSION REQUIREMENTS

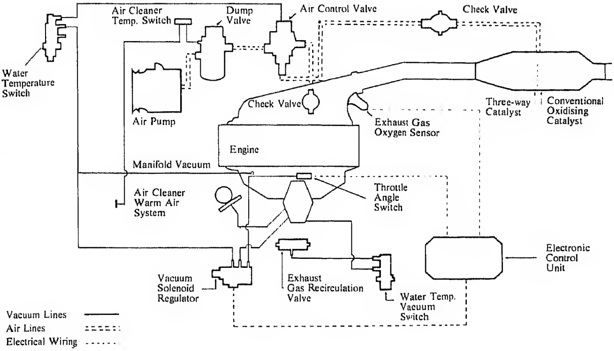
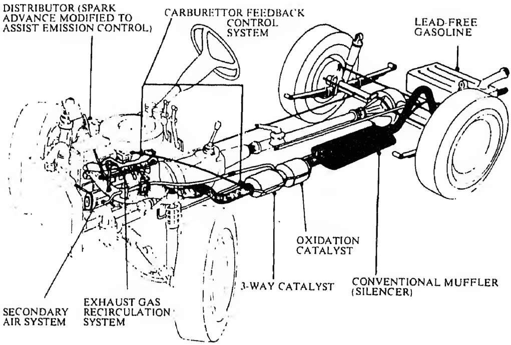


FIG. 3
ENGINE EQUIPPED WITH U.S. FEDERAL EXHAUST EMISSION CONTROL SYSTEM – AS INSTALLED INTO CHASSIS


DISTRIBUTOR (SPARK ADVANCE MODIFIED TO ASSIST EMISSION CONTROL)
CARBURETTOR FEEDBACK CONTROL SYSTEM
LEAD-FREE GASOLINE
OXIDATION CATALYST
CONVENTIONAL MUFFLER (SILENCER)
3-WAY CATALYST
EXHAUST GAS RECIRCULATION SYSTEM
SECONDARY AIR SYSTEM

The "Three Way" (TWC) catalyst for the control of NO_x requires that the engine be operated at the stoichiometric Air:Fuel ratio of 14.7:1, within close limits. This is a "rich-mixture" by the standards of 1983–84 and gives very poor fuel consumption. For a typical 1983 model year car, the fitment of a TWC catalyst will increase (ie: worsen) fuel consumption by around 10%. This is because the typical 1983 car operates on part throttle for 95 per cent of its running time, ie: on lean mixtures with Air: Fuel ratios of 15 to 15.5:1.

The "oxidation" catalyst requires an "oxygen rich" environment in order to operate. This is provided by adding extra air ("secondary air") to the exhaust gas at a point in the pipe just ahead of this catalyst (see Figure 1). The catalyst, being exothermic, rises in temperature as it oxidises the CO and HC and is extremely hot. The exhaust gas should be below 900 C, to prevent the internal catalyst temperature greatly exceeding 1000/1100 C, when the noble metal washcoat will sinter and then break its bond to the ceramic substrate and be blown out of the exhaust pipe.

To test catalyst equipped care the USA has legislated an emission test drive cycle which quickly raises exhaust gas temperature to around 600 C. By comparison the European emission test drive cycle produces maximum exhaust gas temperatures of 350–450 C dependent on the type of vehicle. The US national speed limit of 55 mph prevents catalyst overheating by keeping the exhaust gas well below 900 C. If the speed goes above 60 mph, the secondary air is "switched off", to keep the oxidation catalyst temperatures down, and its efficiency falls sharply. The European cycle is representative of traffic conditions in the congested, narrow, often medieval, centres of Europe's cities. The US cycle is representative of Los Angeles and Chicago, cities of motorways and boulevards.

In European city traffic, many care do not reach speeds where the exhaust gas is not enough to activate a catalyst at an efficient level. The exhaust gas emitted would thus be effectively untreated. In Europe, many drivers regularly (and considerably) exceed 60 mph for sustained periods and reach exhaust gas temperatures which rapidly destroy catalysts. Once this happens, the exhaust gas is ever afterwards emitted untreated unless a new catalyst is fitted. The result would be emission levels comparable to those before UN/ECE Regulation 15 came into effect. A persistent misfire has the same effect of overheating the catalyst, and the use of leaded gasoline poisons the catalyst also making it ineffective. *NB*: The United Kingdom speed limit of 70 mph would not be low enough to prevent "burn-out" on many cars. Continental Europe varies from 100 km/h (63 mph) in Holland through 130 km/h (82 mph) in France to "no limit" as in Germany. In this last country catalyst life could be expected to be measured in days, or weeks, not miles or years.

The "lead-free" gasoline used must be of consistent quality. North American experience shows that the addition of high percentages of Methanol, and some other oxygenates can change the air/fuel enough to impair the catalyst and shorten its life.

Lifetime Capability of Catalyst Technology

US Government Department of Energy studies show that after three years in service less than 50 per cent of catalysts are operating effectively. After a further three years it is thought that it will halve again. The same studies clearly indicate the degree of mis-fuelling (ie: use of leaded fuel) which occurs, and how the percentage of mis-fuelled cars grows as each year passes. Tables A and B illustrate the results of the surveys. Both were conducted in 1982 and were on cars built from 1975 to 1981. The ten States were selected because of their geographic position, and their demographic and industrial/agricultural balances. None is a major automobile producing State.

The US Government's Environmental Protection Agency (EPA) has made a survey, the results of which have been published in the US Federal Register (10 June 1983). This shows that between 20 per cent and 24.4 per cent of all catalyst equipped cars have been tampered with or mis-fuelled with leaded gasoline, thus either impairing or destroying the catalyst. EPA have stated that, in some areas of the USA, 20 per cent of catalysts are removed. The national average is 10 per cent.

Table A US Emissions Performance in Service

State	Number of Vehicles	Okay (%)
Minnesota	307	50.4
Oregon	310	37.7
Washington	312	36.7
Rhode Island	324	49.4
New Jersey	290	43.1
Nevada	275	43.7
Oklahoma	282	41.1
Texas	203	42.7
Louisiana	183	39.9
Florida	309	43.7
Overall	2,885	43.7

Table B Light Duty Vehicle Misfuelling %

Calendar Year	Model Year						
	1975	1976	1977	1978	1979	1980	1981
1978	6.7	5.3	2.7	4.3	—	—	—
1979	10.4	8.2	3.8	2.8	2.5	—	—
1980	12.3	9.8	5.9	5.2	2.8	2.1	—
1981	13.2	11.1	11.3	7.8	2.9	2.6	

Source: US Dept Energy, June 1982

Taken together, these studies by two US Government agencies indicate that the Catalyst has a real-world life of circa three/four years. If a vehicle has a 10 year life, and catalyst replacement is necessary at four years, then for 60 per cent of its life it is producing untreated exhaust gas if that catalyst is not replaced.

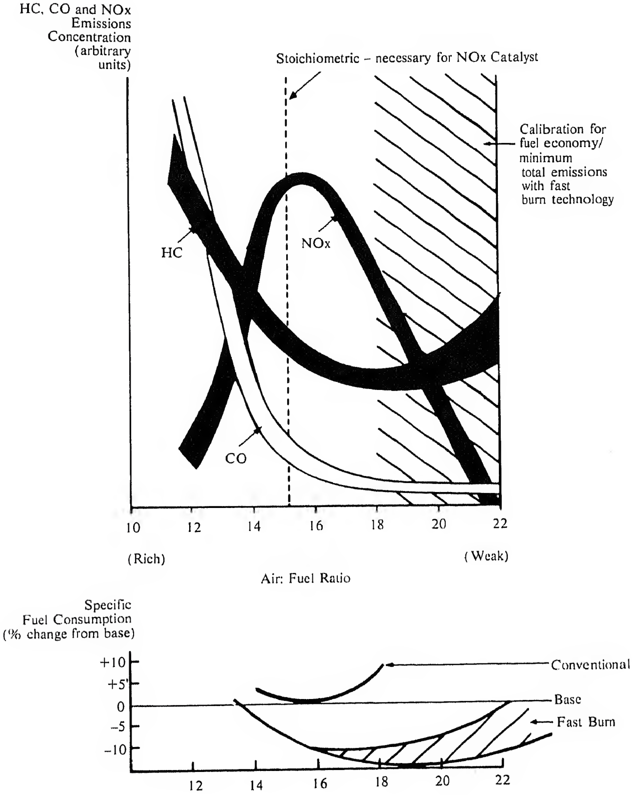
In the catalyst-equipped vehicle a failure of the catalyst, or more often one of its control items, often has the effect of *improving* the driveability of the vehicle. It is unlikely that the driver would notice this and get it fixed. Only a fuel or ignition failure (which may have impaired the catalyst) would be fixed. The catalyst—because it would not be obvious—would be left.

For effective "full vehicle lifetime" emission control, mandatory "in service" testing, maintenance/replacement of catalysts and other parts is clearly required. The studies noted prove this. The US Government requires a 50,000 mile emissions warranty from the vehicle manufacturer, but does not thereafter mandate maintenance or replacement of parts at the owner's expense. Some US States and European Countries have annual or bi-annual inspection requirements involving checks on CO at idle. This is an indication of general condition of the engine. A test to determine if the catalyst works could be devised but it would be of at least one day's duration and would be expensive for the vehicle owner. No US State or European country's Government has to date contemplated a requirement for a complete vehicle annual inspection lasting longer than half-an-hour because of the cost to the citizen. Ford believes it unlikely that Governments would wish to institute mandatory testing, maintenance and replacement requirements for emission systems which would involve high expense to car owners, especially of five year and older cars, who may be the third, fourth or fifth owner. These people are usually among the poorer of a country's citizens.

THE NEW TECHNOLOGY—THE LEAN-BURN ENGINE

The "Lean-Burn" engine is one where the fuel is burned in the presence of relatively large quantities of air, 18 to 22 times the fuel. This compares with the majority of European

FIG. 4
GENERAL EFFECT OF AIR: FUEL RATIO ON FUEL CONSUMPTION AND EXHAUST EMISSIONS IN THE FORD LEAN BURN ENGINE



gasoline engines actually in use (ie: those manufactured over the last five years) which operate at Air: Fuel ratios of 14.5–15.5: 1, generally slightly lean of the chemically correct ratio for complete combustion, (14.7: 1) known as stoichiometric. This restricted operating zone has traditionally been due to poor and irregular combustion at higher Air: Fuel ratios. Operation in the 14.5–15.5 range produces relatively high CO and NO_x, see Figure 4.

There has been intense worldwide effort to increase the combustible Air: Fuel ratio limit in the last 10 years, to reduce emittants and improve fuel consumption. Efficient and consistent operation at Air: Fuel ratios up to and slightly beyond 16: 1 ("Fast-Burn") has been achieved in some production engines by a number of manufacturers, and prototype Ford engines in the range 18–20: 1 are currently under test. Ford Engineers expect to increase this to 22: 1 by the late 1980's/early 1990's. Currently, it has also been possible to increase compression ratios to supplement the lean-burn capability and further improve fuel consumption especially using premium gasolines of 95 RON/85 MON or higher.

Lean-Burn capability is achieved by increasing in-cylinder turbulence before and during combustion and increasing the available flame propagation area, both resulting in very fast burning of the mixture. The key elements of this lean/fast burn concept are embodied primarily in the combustion chamber and inlet port shapes and therefore represent minimal complexity changes from otherwise orthodox gasoline engine designs.

Lean-Burn, because its Air: Fuel mixture is so weak, has natural control of CO and NO_x. Study of Figure 4 shows that the NO_x and CO emissions especially are very low in the operating range 18 to 22: 1. The HC is controlled by careful design of the combustion chamber for nil "dead" volume, and minimum surface area coupled with the maximum of flame propagation area and speed. HC emission levels equal to or below the UN/ECE "04" level are achievable without difficulty.

High speed operation even to the maximum speed capability of the vehicle has no deleterious effect on Lean-Burn engines and protective speed limits would not be required. At low speeds such as are found in City traffic the engine operates particularly cleanly, since it is on small throttle openings and it is well into the lean range above 19: 1 Air: Fuel ratio. The use of leaded fuel can have no effect on its performance or emission capability, and design for unleaded fuel presents no difficulties. Mis-fuelling has no perils for air quality.

Lean-Burn Results

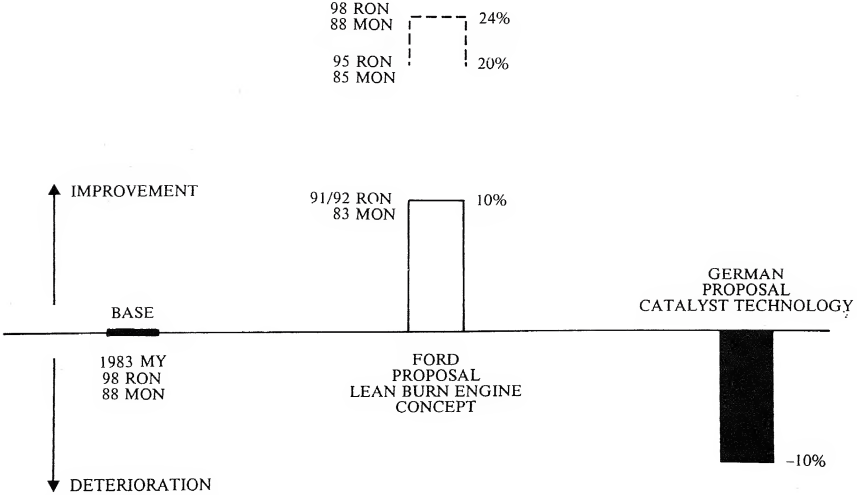
By its nature the Lean-Burn engine is fuel efficient. Figure 5 shows the fuel consumption improvement (ie: reduction) against a 1983 base, for different octane qualities and compression ratios, for an engine optimised for the "04" emission level. The 20 per cent improvement for 95 RON/85 MON (unleaded) is noteworthy, compared to the up to 10 per cent penalty of the catalyst vehicle. Considerably lower emission levels with a maintained fuel consumption improvement are achievable. Ford would welcome an opportunity to enlarge on this aspect at a "viva-voce" presentation.

Life-Time Capability of the Lean-Burn Engine

The Lean-Burn engine does not require in principle any "hang-on" equipment for successful operation. Everything is done inside the combustion chamber. Thus a high standard of consistency of emissions and fuel consumption can be achieved throughout the lifetime of the vehicle, with the minimum of maintenance, and hence cost to the owner. Furthermore, the items which could go wrong (Fuel supply/ignition) are those affecting driveability and would therefore be repaired.

During the early part of their life the general level of emittants from the Lean-Burn engine/vehicle is higher than that of properly operated catalyst equipped vehicles. However, over a 10 or more years life we believe that this will be counter balanced, and that the *overall real world* total lifetime emission levels produced by the Lean-Burn engine will be substantially lower.

FIG. 5
FUEL ECONOMY
POTENTIAL FUEL ECONOMY CHANGES RELATIVE TO 1983 MY VEHICLES



[*Continued*

THE LIFETIME CONCEPT

Ford believes that what matters is not the emission levels achieved when a vehicle is new, nor those produced in its first two years of life, but the mass emission levels produced over the full lifetime of the vehicle.

Our contention is that, over the 10 to 14 year (or longer) life-time of the vehicle, the catalyst system will result in worse emissions than the Lean-Burn system. Catalysts, under US laws, have to pass a 50,000 mile durability test. This is supposedly representative of "customer use". If vehicles are properly driven, maintained and fuelled correctly, this mileage can be exceeded in the "real world". 50,000 miles is approximately five years life. However, as noted, US Government Dept of Energy studies show that most catalysts should be replaced after (circa) three/four years in service. The evidence is that the majority of vehicles DO NOT undergo such replacement. Once the catalyst has ceased to function effectively, the exhaust gases are emitted largely UNTREATED to the atmosphere.

If a vehicle has a life of 10 years, and replacement is necessary at (say) four years, then for 60 per cent of its life it is producing untreated exhaust gas. This cannot be satisfactory in the real world.

The price of a replacement catalyst in the United States for a US Ford car varies between $200 and $400, dependent on the vehicle/catalyst type. Other manufacturers' prices are similar. We believe that the median price of $320 (£206 at $1.55 to £1) would be a realistic one in the United Kingdom. To compel car owners to spend sums of this magnitude, plus the labour costs of removing the old part and fitting the new, at periods of four years or so seems unreasonable. It would however, be necessary to do so in order to maintain for the lifetime of the vehicle any improvement in air quality obtained by the fitment of catalysts.

In the Lean-Burn engine the fuel is burned in such a way that the exhaust gases are *naturally* low in emittants. Since there is little or nothing to go seriously wrong this means that the quality of the emittant gases is not dependent on the replacement of essential parts. Thus over the life time of the vehicle the emittant levels should remain reasonably constant, and at lower levels than the current (1983) EEC requirements and, indeed, those in Directive 83/351/EEC for 1984–86 (the UN "04" levels). Fuel economy is superior.

CONCLUSIONS

Comparing and Summarising

Catalyst Technology means:

- —complex and expensive vehicles
- —lead-free gasoline must be available everywhere in Europe
- —universal European speed limits, not greater than 100 km/h
- —around 10 per cent worse fuel consumption compared to the 1983 equivalent vehicle
- —compulsory and expensive maintenance to ensure lifetime capability

Lean-Burn Technology means:

- —relatively simple and inexpensive construction
- —tolerant of leaded, unleaded or lead-free gasoline (of equal octane value)
- —20 per cent improved fuel consumption compared to the 1983 equivalent vehicle
- —current (or possibly reduced) maintenance coupled with lifetime capability

It is the view of Ford Motor Company Limited that the Catalyst represents the Technology of the 1970's, and Lean-Burn the Technology of the 1980's/90's. In view of the continued necessity to conserve the world's oil resources, the possible choice of catalyst emission control systems which demand A GREATER USE OF CRUDE OIL than alternative, newer systems must be resisted. It must also be resisted on the grounds of consumer cost—for any system which relies for its life time capability on the vehicle owner replacing, at high cost, significant parts cannot be satisfactory. The consumer is looking for less cost and better results. Ford believes Lean-Burn offers both.

Ford is convinced that the Lean-Burn engine offers greater benefit to the public at large, in respect of both vehicle emissions and fuel economy than the catalyst concept.

PRESENTATION OF FURTHER EVIDENCE

Ford requests the opportunity to enlarge on these matters by viva-voce presentation of evidence to members of the Commission either at the Commission's headquarters or at our Dunton, Essex, Research Engineering Centre, where the new technology can be demonstrated.

GLOSSARY OF TERMS

Lead-free Gasoline—gasoline chemically cleaned of lead delivered through chemically clean distribution systems.

Unleaded Gasoline—gasoline to which lead has NOT been deliberately added, delivered through the normal system.

Mis-Fuelling—in a catalyst equipped vehicle, the act of filling the tank with leaded gasoline and so operating.

Catalyst—a device for creating or improving a chemical reaction without itself changing.
  Reducing Catalyst—a catalyst which causes the removal of oxygen and thus chemically changes a substance.
  Oxidation Catalyst—a catalyst which in the presence of excess oxygen causes a substance to take up the oxygen, ie: "oxidise".
  "*Three-Way*" (*TWC*) *Catalyst*—a reducing catalyst primarily for the reduction of NO_x to Nitrogen, it also tends to reduce the CO to Carbon, and gives some control of HC.

Ceramic Substrate—a honeycomb type structure made of a ceramic (for example sintered aluminium oxide) upon which the catalytic material—usually a noble metal—is mounted in a very thin layer or "washcoat".

Stoichiometric Ratio—the Air: Fuel ratio (normally by weight) for complete burning of the fuel. In a gasoline engine, 14.5 to 14.8 dependent on the specific gravity of the gasoline and the inlet air temperature. (*NB*: By volume with the gasoline fully vapourised, between 55 and 60:1). If the gasoline contains alcohol the ratio changes dependent on the oxygen content of the alcohol.

Lean-Burn—a mode of gasoline fuelled reciprocating engine operation where the Air: Fuel ratio is greater than 18:1.

Fast-Burn—a mode of gasoline fuelled reciprocating engine operation where the Air: Fuel ratio is around 16:1.

Emission Drive Dycle—a pattern of vehicle operation simulating certain in-use driving conditions. This is achieved by driving the vehicle, which is mounted on a dynometer, according to that pattern.

US Drive Cycle—an emission drive cycle which is based on tests made in the city of Los Angeles, California. It has a length of 7.5 miles (12 km), a maximum speed of 58 m.p.h. (93 km/h) an average speed of 19.6 mph (31.5 km/h), and exhaust gas temperatures of around 600 C.

European Drive Cycle—an emission drive cycle based on tests made in London, Paris, Turin and the Ruhr. It has a length of 4.05 km, a maximum speed of 50 km/h, and average speed of 19 km/h; uses only first, second and third gears, ie: never gets into top or overdrive, and exhaust gases rarely exceed 400 C.

"*In Cylinder*" *Turbulence*—achieved by causing the inlet air and fuel gas mixture to both tumble over and over and to spin (double helix action) before entering the cylinder, then to be further excited and "tumbled" by the head shape of the compressing piston and the specially shaped combustion chamber.

Flame propagation (*area*)—the way in which the "wall" of ignited gas moves from the spark plug to the outermost part of the combustion chamber. Evenness of development of the "wall" and its speed are important.

Driveability—the response of the vehicle to the instructions of the driver, usually via the accelerator pedal. Poor driveability is "stumble" or "hesitation", "stalling" or "hunting" by the engine on pressing down the pedal—assuming the right gear for the load and speed has been selected. Also "tractability"—the capability of top gear "pulling power" from low road speeds.

Memorandum from the Talbot Motor Company Limited

ACID RAIN

The Talbot Motor Company (TM) is, as you know, an integrated part of Peugot SA (PSA) and, as such, is involved with the problem of acid rain at a consultative level.

TM participates directly in SMMT and its technical committees whilst PSA are participants in GRPE which is the UN body dealing with problems of this nature, CSCA (the French equivalent of SMMT) and, because of its heavy involvement in the United States, with the US equivalent (MVMA).

TM strongly supports the general view that the mechanism of the formation of acid rain is insufficiently understood and that greater efforts need to be made in the study of Air Quality levels before the proportion of acid rain which can be attributed to the motor vehicle can be decided and hence the degree of corrective action which could be justified. We believe that the proportion of the relevant pollutants caused by the motor vehicle (including trucks) is of the order of five per cent—SMMT say 7.5 per cent and other sources as low as two per cent whilst the extremes suggested by our experts are from 2.3 per cent to 5.9 per cent dependent on the hypothesis used.

It should be borne in mind that some 50 to 70 per cent of the relevant emissions are sulphur based and that these are almost wholly of non-automotive origin whilst only less than one third of the remainder (oxides of nitrogen—NO_x) is of automotive origin. Hence it can be seen that total elimination of NO_x from new vehicles would only remove between two and 7.5 per cent of the total problem—ignoring the existing vehicle park.

In practice it is not feasible to remove totally NO_x from vehicle exhausts and, therefore, the real reduction would be significantly less.

In summary, the position of TM is as follows:—

1. We are concerned about the problem of acid rain but feel strongly that previous Air Quality studies show that the role of the motor vehicle and the car in particular is not a significant factor.
2. If it should be shown that as a result of future Air Quality studies there is a case for reducing the contribution of the motor vehicle to the problem then it is virtually certain that this will be to reduce NO_x emissions. The technology involved is well understood by virtue of work already done both for European and, particularly, for the United States market.

   As this technology is well known and available within PSA, we feel that studies of the causes of acid rain are properly the province of Air Quality studies to define the mechanisms. We suggest there should be an overall programme to improve the situation. This is, we understand, the view held by all of the major European manufacturers.
3. The approach to NO_x reduction by means of catalytic converters proposed by the Federal German Republic is not, we believe, based on technical requirements. It will be expensive in terms of initial cost and energy consumption.
4. The alternative strategies available, if it should be that reductions in automobile emissions are required in Europe, are the use of catalysts, as discussed above, or the use of better combustion techniques within the engine and, without doubt, we favour the latter as being the more fundamentally correct, less expensive in cost to the car buyer and more energy efficient. Additionally this approach is more

likely to be free from deterioration in emission performance due to owner neglect or abuse.

G. H. Whalen
Managing Director

16 May 1984

Memorandum from The Automobile Association

The Automobile Association welcomes the House of Commons Environment Committee Inquiry into acid rain and has pleasure in submitting the attached paper which concentrates on the contribution of motor cars to the alleged poisoning of the ecosphere.

The submission is accompanied by two appendices. Appendix A raises the question of whether Europe is right to demand catalysts for its cars from 1986 onwards or not. Appendix B looks at the general effect of the Air: Fuel ratio on exhaust emissions.

Since its preparation EEC proposals regarding lead in petrol and vehicle exhaust emissions have been announced. The Association was asked by the Department of Environment for its comments on the proposals almost by return and I attach a copy of our response which might be helpful to your Committee.

The Association is grateful to the Committee for allowing it an extension of time for its submission to be entered and hopes that its views will be of some assistance to the Committee in its deliberations on this complicated—and sometimes emotive—subject.

K G Faircloth
Assistant Managing Director

30 May 1984

Copy of letter from the Automobile Association to the Department of Environment commenting upon EEC proposals regarding lead in petrol and vehicle exhaust emissions.

Thank you for your letter of the 17 May, enclosing the Communique on the European Commission's proposals for lead in petrol and other vehicle emissions. The English translation received subsequently was helpful and appreciated.

In view of the comparatively short time scale, I felt that I should provide you, now, with the Association's initial comments, upon which we will elaborate when we have been able to fully consider the implications of the proposals.

Lead in petrol

The Association is not opposed to the removal of lead from petrol, but it is essential that leaded petrol continues to be available for sufficient period so as to enable the consumer to obtain full economic value from existing vehicles which are not able to function on lead free petrol.

Limit values on exhaust emissions

The proposed reductions in limit values on emissions are being studied, and it is not wished to comment on these values at the present time.

As regard the second stage; post 1995, for which technical decisions have yet to be made, the uncertain cost burden of catalyst technology must be a major consideration to set against effectiveness in reducing emissions.

Uniformity

In order to preserve freedom of movement by the motor vehicle throughout the community, it is essential that proposals are implemented uniformily, particularly in relation to the availability of leaded and lead-free petrol.

> *Cost*
>
> The correct balance will have to be achieved between, on the one hand, the cost of implementing the proposals and the need to economise on irreplaceable imported energy and on the other, the protection of health and environment. The Association, I would emphasise, recognises the need for effective steps in this respect.
>
> It is, however, suggested that it would be unreasonable to expect the motor vehicle user to bear the total cost of remedial measures. The suggestion that lead-free petrol should be sold at a lower price than leaded petrol is welcomed. The difference should not, however, be achieved by a means of an increase in the cost of leaded fuel. As it appears that the cost of refining will rise, the price differential is likely to be a matter of fiscal adjustment.

I hope that these brief comments will assist in determining Government views for the Environment Council meeting at the end of June. A full response will be provided as soon as possible, after which we would welcome discussions on any areas in which there is apparent difference of view between us.

K G Faircloth,
Assistant Managing Director
25 May, 1984

ACID RAIN

Submission by The Automobile Association

Summary of Main Points

1. Transport's contribution to acidity in the air must be seen against the general total background of acidity generation and not in isolation.—*Section 1*

2. Motor vehicles are responsible for only about 25 per cent of all NO_x emission or about eight per cent to 10 per cent of the total acid rain generated in the UK.—*Section 2*

3. Evaporative losses from oil refineries, petro-chemical and other industrial plants are primary sources of air pollution.—*Section 3*

4. Vehicle exhaust emission: the three-way catalyst may not be the answer in the UK's motoring conditions.—*Section 5*

5. The primary source of NO_x pollution is the combustion of coal and oil. The motor car's contribution to the total acid rain burden is small.—*Section 6*

6. The fitting of three-way catalysts may present considerable technical problems, would increase manufacturing costs and impose a cost burden on motorists of between £200 and £450 every three to four years.—*Section 7*

1. *Introduction*

Concern has, of late, been expressed in various quarters in the UK and abroad regarding the increase in the level of acidity in the atmosphere, in acid precipitation in rain, snow, mist and fog, or deposition of dry gaseous or aerosol particulates on trees, crops, soil, lakes and rivers.

The encroachment of urbanisation, the rise of large industrial complexes, large power stations, oil refineries, petro-chemical plants, as well as major and drastic changes in agriculture, including the widespread use of artificial fertilizers and other agro-chemical agents will all have tended to raise the background level of acidity.

Transport, which is claimed by some to be a major contributor to any rise in acidity level in the ecology of North America and Europe, may impose an additional burden, but it should be seen against the general, total background and not in isolation.

The contribution of transport to SO_2 emission is very small, for the following reasons:—

(a) Kerosene as aircraft fuel and

(b) gasolene for road transport are virtually free of sulphur;

(c) it is quite small in diesel fuel for road transport and agriculture: even in rail and sea transport it is quite modest;

(d) only large sea-going vessels use the heavier grades of fuel oil, which contain sulphur.

Compared with land based, fixed installations, these widely dispersed sources of SO_2 emissions are of little significance.

In any case, it is wrong to oversimplify the "acid rain" problem by stating that all the gaseous SO_2 will be converted to SO_2^-, which is acidic.

In the densely populated and highly industrialised zones of Western and Central Europe the major sources of NO_x emissions are man-made, and this includes transport, particularly road transport.

2. *The Contribution by Motor Vehicles to Acidification*

The effect which exhaust gas emissions from motor vehicles can have on the ecology in general and on "acid rain" in particular warrants much more research and detailed analysis of any links there may be than it has received to date.

Motor vehicles are, without a doubt, emitters of NO and NO_2 as well as reactive hydrocarbons and aldehydes which, in turn, influence the rate of production of substances in the atmosphere which assist in the generation of "acid rain".

Impending changes in motor fuel composition, such as a higher proportion of aromatic functions, blending in of methanol and its co-solvents, or MTBE, to compensate for the loss of octane value which the drastic reduction and/or total elimination of lead alkyl additives in gasolene fuel will bring about, will also modify the potential for "acid rain" generation from the totality of these various interlinked gaseous emissions.

Evolutionary developments in engine management, particularly better combustion control under part load conditions, may counteract the deterioration in gasolene quality which is currently taking place in Europe and North America. The reference fuels which manufacturers use, quite legitimately, for the purpose of establishing fuel consumption as well as exhaust gas emission levels in conformity with the ECE 15 test cycle, are no longer representative of commercially available motor fuels on sale in bulk in many parts of Europe.

All of these factors and, above all, the mode of driving, will affect the exhaust gas temperature and the level of pollutants and their composition. If a catalyst were to be fitted, its effectiveness would also be substantially dependent on the exhaust gas temperature. For a three-way catalyst to be effective in reducing pollution its core must not drop below about 350°C to 400°C, nor must it rise above about 850°C to 900°C.

In urban stop–start motoring many catalysts may not reach the ideal temperature of around 600°C and hence the reduction in pollutants actually achieved in towns may fall short of expectations. Also it should be remembered that motor vehicles are currently responsible for only about 25 per cent of all the NO_x emissions originating in the UK or about eight per cent to 10 per cent of the total "acid rain" burden being generated in the UK.

3. *NO_x Emissions and their Interaction with other Airborne Pollutants*

Carbon monoxide and hydrocarbon emissions arise from incomplete combustion of fuel. Evaporative losses from oil refineries, petro-chemical plants, production of plastics, synthetic rubber, man-made fibres, paints, industrial solvents and fermentation processes and local fuel storage tanks, are primary sources of air pollution and are probably of greater significance than hydrocarbon emissions from modern motor cars in a reasonable state of tune. Some hydrocarbons are more reactive with NO_x than others.

A great deal more work is needed to determine the relative rate of activity each broad group of hydrocarbons has in promoting secondary pollutants and, via this chemical path, increase the formation of HNO_3, nitric acid. For instance, the total elimination of lead alkyls from gasolene may have unexpected side effects. In order to maintain the octane rating of motor spirit, further secondary and tertiary stages of refining are likely to be employed, resulting in higher proportions of low boiling point aromatics and olefins. These in turn are more reactive with NO_x and hence would tend to raise nitric acid generation in the atmosphere, though the total level of hydrocarbon emissions from motor cars remain unaltered, when compared with the current HC emissions using leaded motor spirit.

4. *How Far Does NO_x Travel Before it Descends as "Acid Rain"?*

The actual range of transportation of NO_x by natural air currents and prevailing winds is far less well-documented than the corresponding spread of SO_2 from clearly identifiable sources. As far as motor vehicles are concerned far less of their NO_x is likely to reach the lower atmosphere, where winds will carry the pollutants eastwards over considerable distances, than in the case of fixed installations with tall chimney stacks.

It would appear that the most severe concentration of nitric acid fall-out occurs on a fairly narrow band sweeping eastward from about Le Havre across the Ruhr to Poznan (Poland). About three quarters of that severity will be in the following areas: London and much of South East England, France around the Paris area, Benelux, the industrial heartland of both West and East Germany, Poland and much of Bohemia (Northern CSR). Many woodlands in Western and Central Europe thus lie under this nitric "acid rain blanket".

At about half the maximum sulphate precipitation level this blanket covers much of Europe; few places will escape in England and Wales, France, both Germanys, Switzerland, Austria, most of the Baltic Southern coastal regions, not forgetting the tip of Southern Sweden.

5. *NO_x Emissions from Motor Vehicles*

The vast majority of motor cars in the UK are powered by gasolene fuelled engines and, unlike some Continental countries, the proportion of diesel engined motor cars is unlikely to be of real significance; an eight per cent market share of new car registration in the UK is still several years away and LPG as a transport fuel has not made much of an impact on the UK scene.

Our concern must, therefore, be with all three primary pollutants: CO, HC, and NO_x. It may be convenient, even politically expedient, to approach the problem of how to reduce car exhaust emissions effectively and dramatically by insisting on a level of emissions which, even in the somewhat arbitrary ECE15 type test can only be met by the fitting of a three-way catalyst system. But such a move greatly oversimplifies the complex problems to an unacceptable degree.

To begin with there is the problem of non-availability right across Europe of lead-free gasolene, and it will take about seven to 10 years before an adequate supply of premium grade lead-free gasolene can be guaranteed, at least along the major trunk routes of Western and Central Europe. All three-way catalysts have to rely on total absence of lead and other heavy metals in fuel or oil which may come into contact with the core of the catalyst, for these would poison catalysts, making them ineffective in a relatively short time.

About half the motor fuel sold in the UK is consumed in relatively short distance motoring under severely speed-restricted conditions. Under such operating conditions three-way catalysts are unlikely to reach a sufficiently high exhaust gas temperature to fully activate the precious metal covered stainless steel or ceramic core.

The reduction of the three pollutants will therefore be around one third to one half that achieved in the USA, where urban express ways and longer trip distances as well as higher average speeds result in catalyst core temperatures being around 550°C to 600°C most of the time, whereas in London or Birmingham traffic they may barely reach the minimum required temperature at which a catalyst will reduce the pollutants (about 350°C to 400°C).

6. *What Proportion of NO_x Emission in the UK is Due to Motor Cars?*

Currently the primary source of NO_x pollution is still the combustion of coal and oil, each accounting for about a quarter of the total emitted in the UK.

Over the past decade the contribution of road transport to the total annual NO_x emission has been around 25 per cent. An additional two per cent to three per cent was contributed by rail transport; domestic use accounted for about three per cent; about 45 per cent was accounted for by power stations; industrial and commercial users contributed around 25 per cent.

There can be little argument about the fact that an NO_x emission rise follows the trend of increases in the consumption of petroleum products, from heavy fuel to gasolene, over the last 40 years. Currently the total NO_x emission level in the UK, of which about 70 per cent will drop back onto the UK as dry gas or nitric acid, is about twice the annual rate recorded by the Warren Spring Laboratory for the period 1905 to 1940.

Since the data differs so markedly from the 1974 Annual Abstracts of Greater London Statistics, in which the motor vehicle (in particular the private motor car) emerged as the prime emitter of NO_x, an explanation is called for.

Almost all the electric power consumed in London is imported from outside the GLC administered area. No contribution from these prime polluters will, therefore, be recorded in these annual statistics. The same applies to the capital's extensive electrified rail transport system. In addition traffic density in London is significantly above the UK norm.

All this then led the statisticians to allocate about 54 per cent of the capital's NO_x pollution as originating from motor vehicles, with 70 per cent of that being emitted from gasolene engined vehicles, ie cars and light vans. Compared with the Warren Spring Laboratory 1983 Report, which covers the whole of the UK, the contribution to NO_x emissions as a percentage of the total has been over-represented by factor of 2.2.

Taken in conjunction with SO_2 emissions, which are the prime cause of acidification of the atmosphere, the actual contribution by gasolene engine powered motor cars is only around eight per cent to 10 per cent of the total "acid rain" burden being generated in the UK.

It is, of course, possible to make the motor car "the villain of the piece" by defining the boundaries of an ecological site in such a manner that all imports of NO_x from outside a relatively small area are excluded, for this would leave the mobile emitter, the motor vehicle, as the prime polluter. This is the explanation for some ecologists and other researchers allocating 40 per cent to 45 per cent to motor cars as the cause of "acid rain" damage to the environment.

7. *Technical Possibilities for Reducing Pollutant Emissions From Motor Vehicles*

In the case of diesel engined vehicles the major pollutants they emit are NO_x, generally at a significantly higher level per gallon of fuel burned than for gasolene engined vehicles, soot and smoke, ie particulates. Diesel engined vehicles also emit some small amount of CO and HC, but generally at a much lower level than corresponding gasolene engined ones. The level of emissions is much more affected by poor maintenance in the case of fuel injection, particularly so in the case of diesels, than has generally been reported. In the case of neglected vehicles it can be two or three times the type test emission values.

The data on which one can base regulatory policies for optimum reduction of emissions from motor vehicles is very limited. What does exist is based almost entirely on dynamometer testing to one or other of the following test cycles:

1. US Federal 2. ECE 15, 3. the Japanese cycle

For one and the same vehicle quantitatively very different values of the three primary pollutants CO, HC and NO_x will be obtained, depending on the test cycle chosen.

To equate US data with either European or Japanese ones can be very misleading. The average speeds of the Japanese and the European test cycle are each very much lower than that of the US Federal ones. Consequently cars tested to the US Federal cycle will operate at much higher average exhaust gas temperatures (about 600°C) than would apply in the ECE 15, where 350°C to 450°C is more common.

Three-way catalysts rely on the exhaust gasses passing over the precious metal in the core not dropping below about 350° C. A reduction of 50 per cent to 60 per cent instead of 90 per cent in pollutants is likely under European operations as against the US travel mode.

If the temperature drops below that value, then catalyst action can be quite low. In the cooler European test cycle such a system may therefore not give the same pollutant reduction benefit as was found in the US tests.

The only reliable assessment of the effect of regulatory measures would be to compare in-service emission performance of a wide range of motor cars over their typical range of engine power utilisation, which is primarily a function of traffic flow speed and terrain, and moreover monitor that over extended periods, to ascertain the degree of fall-off in combustion control, catalyst efficiency and durability, with age and mileage. Such data do not exist in sufficient volume yet.

For typical current European and Japanese motor cars, within the one to two and a half litre engine capacity range, fuel economy has been found to be at its optimum for average rate of progress within the 60 km/hour to 85 km/hour band. This generally also gives the lowest CO and HC emission levels. At lower average speeds fuel economy suffers and emissions of CO and HC rise quite steeply.

On the other hand NO_x tends to remain about the same. Increasing the rate of progress well above optimum fuel economy speeds tends to lower HC emissions but may increase NO_x emissions, with the sum of HC of NO_x remaining nearly constant. CO emissions generally do not change much as the speed of the car is raised.

Because of this relationship between vehicle speed and total emission level of the three principal pollutants, it is possible to over-estimate the CO and HC burden by a factor of around two, if one adopts the unmodified ECE 15 test cycle as a yard-stick rather than a typical mixed Urban, Rural and Motorway route.

Bearing in mind all the above doubts about the correctness of basic assumptions made by various protagonists, one is entitled to question whether the extreme measure of making the fitting of three-way catalysis to cars operating in the UK, or the EEC, mandatory by 1986, 1988 or even 1990, is either necessary or can be recommended on the basis of cost/benefit.

The fitting of three-way catalysts may present considerably technical problems to some European and UK based car makers, at least in the time scale allowed by the Federal German Authorities. Above all it would *increase manufacturing costs* of small to medium sized cars by some six per cent to 12 per cent, whilst at the same time *reducing power output* units by about 10 per cent. All this would incur a *fuel economy penalty* of about 10 per cent to 12 per cent.

The need to replace such three-way catalysts every three to four years would impose a further economic burden on ordinary motorists of the order of an extra £200 to £450, depending on make and model. Just because it appears technically feasible, admittedly at considerable cost to all concerned, namely vehicle manufacturers, motorists and the National Economy (for it would inevitably raise oil consumption) is no valid justification to demand such drastic engineering changes within a few years time, on all new cars. The most that such a drastic step could bring about is a reduction of "acid rain" producing emissions from motor cars of about six per cent to eight per cent during the first year after its introduction; even after 10 years it would still only be around 25 per cent to 35 per cent.

In terms of reducing the overall "acid rain" burden from all sources the contribution that the fitting of three-way catalysts could have, would, however, be less than one per cent in the first year of their deployment and only about three per cent some years later.

A reduction from the current permissible maximum emission levels, particularly HC and NO_x, should not present insurmountable problems to manufacturers in Europe, if the reductions were to be of the order of one third to one half. This would allow such manufacturers to perfect their "fast-burn" or "lean-burn" power units, which promise further overall reductions in fuel consumption. It would also achieve emission levels per vehicle equal or better than those achieved in the USA on 1978 to 1982 models, for the average US motor car has much larger sized engines than its European and Japanese counterparts and is less fuel efficient.

Adopting the above approach of aiming to achieve within 5 years a 30 per cent to 50 per cent reduction of $HC + NO_x$ emissions right across Europe could have the overall effect on "acid rain" generation of reducing it by about half a per cent during the first year of its mandatory introduction, rising to about one and a half per cent to two per cent within a decade. The extra manufacturing cost per car would be £50 to £80.

Further arguments in support of *not* opting for extreme measures are:

1. All the available data suggests that a doubling of airborne pollutant burden does not produce anything like a doubling of "acid rain" burden, let alone increase acidity of soil and ground water in direct proportion.
2. Will halving of such airborne pollutants reduce the acidification of the ecosphere by 40 per cent, 30 per cent, or less?
3. Three-way catalysts deteriorate with age, mileage, and oil escaping past piston rings and seals, to say nothing of accidental or deliberate mis-fuelling with gasolene containing lead or other heavy metals. What will their effectiveness be then, particularly under light load conditions, such as stop-start motoring in large urban conurbations?

8. *Summary*

The paper has attempted to relate the contribution of motor cars to the alleged poisoning of the ecosphere by "acid rain".

As far as emissions from motor cars are concerned, these contain virtually no SO_2 and in the UK only about a quarter of the NO_x emissions are attributable to motor vehicles. About two thirds to three quarters of "acid rain" is caused by chemical transformation of SO_2 to H_2SO_4 and only about a quarter is due to NO_x. The "acid rain" producing emissions from motor cars contribute only about eight per cent to 10 per cent of the UK's total "acid rain" burden.

The mandatory introduction in the near future of much more severe emission regulations is not only subject to the law of diminishing returns, it may also have a very low cost/benefit merit rating. That certainly applies to motor vehicles where the cost of introducing legislation requiring three-way catalysts to all new cars would amount to £700 million, for the UK alone, during the first year of its implementation. The effect on the "acid rain" burden would, however, be only about a one per cent reduction.

Progressively the cost would increase to about £5 billion to £6 billion per annum by year 10 after the introduction of three-way catalysts. It would take over a decade before hald the current, non-catalyst car population would be phased out. The reduction in the "acid rain" burden 10 years after the introduction of three-way catalysts would still only be about three per cent.

With the current trend in the UK away from heavy industry primary products, such as iron and steel, non-ferrous metal and heavy chemicals, into the service industry sector, better combustion control and higher degrees of insulation to reduce heat losses in public and private buildings, the general level of SO_2 and NO_x emissions are likely to stabilise at the current level and will probably decline again.

The problem of "acid rain" despoilation of our environment may, therefore, not call for quite such drastic remedies as yet once more penalising motor transport with all the knock-on effects this is likely to have.

We suggest that for an additional cost of £50 to £80 per new car, instead of £350 to £550 which the fitting of three-way catalysts implies, it may be possible to achieve between one half to two thirds of the potential exhaust emission reduction claimed for by the protagonists of the three-way catalyst solution.

This alternative of opting for much leaner air–fuel mixtures would further reduce fuel consumption, to the point where the initial extra cost in having special combustion chambers, knock limiters and other control devices fitted, would pay for itself within 12 to 16 months.

This, and the fact that one could achieve within a decade after the introduction of "lean-burn" or "fast-burn" on a massive scale an effective reduction of "acid rain" level by about one and a half per cent to two per cent, should be set against the arguments for three-way catalysts which inevitably lead to a marked increase in fuel consumption.

APPENDIX A

WILL EUROPE DEMAND CATALYSTS FOR ITS 1986 MODEL CARS OR NOT?

Although the Federal German Minister of the Interior Herr Zimmermann announced in July 1983 that *all* new cars registered in West Germany after 1 January 1986 would have to run on lead-free gasolene and require three-way catalysts, it is most unlikely that this target date will be maintained. A two year delay is probable for a variety of reasons, particularly the physical inability to carry through the 50,000 mile endurance testing on the dozens of different makes and models in the brief time span still available.

There are soundly based arguments against premature introduction of US type emission levels and three-way catalysts, such as:

1. It will require the availability right across Europe of lead-free gasolene is mobility is to be maintained. This cannot be achieved by January 1986. It cannot even be guaranteed throughout Federal Germany, for it requires hundreds of special fuel tanks and fuel pumps to be installed in towns and on major routes. These and the additional fuel tankers must *never* handle ordinary premium or regular grades of gasolene containing lead alkyl additives.

   Even a low concentration of lead such as 0.005 g/litre poisons catalysts and thereby renders them useless. In fact many grades of non leaded fuel contain some low level of lead which must be removed by the refiners.

2. The EEC at Brussels would have to rescind the currently mandatory requirements for all commercially sold grades of petrol in the Common Market to have a minimum of lead alkyls of 0.15 g/litre of petrol which was set to ensure that current ranges of engines do not suffer premature wear or failure, for lead compounds act as solid lubricants.

It is most unlikely that the pace of Euro legislative procedures can be so accelerated out of all recognition as to actually get all co-signatories of the Treaty of Rome to ratify such a change by 1 January 1986.

3. The French and Italian Governments are reluctant to support any move to eliminate lead altogether for they foresee considerable cost penalties to their economies. The fuel consumption per car will increase by between 10 per cent and 12 per cent. Also the French and Italians favour small cubic capacity engines and so do their car producers. Such small power units do not live happily with three-way catalysts and neither the French nor Italian motor manufacturers are ready yet to mass-produce small engines which can be totally reliable and durable when running day in day out on lead-free gasolene.
4. There is considerable opposition by the major car producers in Western Europe, including the multinationals, to rush into new technology. For having three-way catalysts operating under European conditions would present different problems to those experienced under US motoring conditions.
5. Several manufacturers, including Ford of Europe, prefer a different approach altogether to reduce air pollution, namely a lean burn, which under real like European motoring conditions would achieve nearly the same low pollution level as a three-way catalyst. The Jaguar Fast Burn concept is also a good candidate.
6. It is a mistake to assume that one can compare US Federal results with ECE test results.

   Britain does not oppose lower emission levels being set—but does oppose catalysts—and requires that fuel economy must also improve.

   With the introduction of low octane lead-free gasolene there would inevitably be a worsening of fuel economy and fitting catalysts would further worsen the situation both as regards the test cycle consumption figures and above all under real-life operating conditions.

   It would be imperative to maintain lead-free gasolene at a minimum of 95 RON octane level. To-date there has been no agreement yet among all the interested parties, primarily the oil companies, as to what blends and RON and MON levels should be mandatory for lead-free gasolene grades.

Catalysts or Not?

The European Drive Cycle is a cycle based on tests made in London, Paris, Turin and the Ruhr in the late 1960s. It has a length of 4.05 km (2.53 miles), a maximum speed of 50 km/h (31.25 mph), an average speed of 19 km/h (11.9 mph), and it uses only first, second and third gears—the driver never gets into top or overdrive—and exhaust gases rarely exceed 400° C. This is below the temperature required to obtain optimum detoxing of the gases passing over the precious metal coated core matrix of the type of catalyst in use in the USA.

The test cycle does not take into account motorway speeds which may be in excess of 130 km/h (81.25 mph). If catalysts were to become mandatory then an overall speed limit of around 100 to 105 km/h (62.5 mph to 65.6 mph) may have to be enforced right across Europe. This runs counter to the trend of European long distance motoring speeds, which currently is around 120 to 140 km/h (75 mph to 87.5 mph) and would require legislation to that effect being passed in all European countries.

Within about three to five years time it may be possible to fit three-way catalysts which can be made Autobahn proof—provided a speed limit were to be introduced. It could be as high as 160 km/h or as low as 110 km/h, depending on the type of catalyst and the size of its central core. These speed limits might prove difficult to enforce.

But the real problem is that, if such a catalyst is about 90 per cent efficient for unrestricted long distance motorway driving, its efficiency of converting the allegedly harmful emission constituents could drop to well below 50 per cent for the much slower progress in urban districts, for any catalyst fitted needs to reach and maintain a minimum working temperature.

If that is not provided by the exhaust gases passing over the precious metal surfaces which are embedded in or attached to a ceramic or a stainless steel matrix, then the efficiency of conversion drops to an unacceptably low level.

The way to overcome this is to burn fuel downstream of the power unit. Contrary to what the propagandists for compulsory fitting of catalysts believe, the US type three-way catalyst as fitted to European export models to the USA is *not* the proper solution for it is designed to operate on a very different driving cycle—relatively faster in town and slower on the open highway. In other words the operating temperature range of the catalyst is narrower than for the typical European conditions generally and for the ECE driving cycle specifically.

The field test data gathered by Audi-VW, BMW and Daimler Benz is at an early stage and both Audi-VW and BMW have admitted that they *hope* that their new type catalysts will last about 50,000 km on lead-free fuel—but cannot be certain of this, for all tests have been run on reference fuels which bear little resemblance to what the oil companies will supply in the late 1980's and 1990's.

What is certain is this: Fuel consumption will rise by 10 per cent to 12 per cent, power output will drop by 10 per cent and extra costs to the new car purchaser will be between £475 to £580 on the Audi-VW range and £650 to £800 on the Daimler Benz range. Obviously, the more expensive the basic car, the less significant this inevitable extra new car cost, which will never be fully recoverable when selling the car into the used car market, for the catalysts are notoriously short-lived.

In the case of Daimler Benz the extra cost will be from four to seven per cent, for Audi between six and a half and eight and a half per cent, whereas for the mass transport, popular VW range it will amount to eight and a half to 10 per cent. The smaller the car, the more significant the negative effects outlined above.

This is the principal fear of the French and Italian car manufacturers who are, therefore, resisting the introduction of catalysts. Ford of Europe are similarly disinclined to adopt catalysts, unless compelled to do so by European legislation. Their option would be to import complete engines from their under-utilised Mexican plants.

APPENDIX B

GENERAL EFFECT OF AIR: FUEL RATIO ON EXHAUST EMISSIONS (already printed Fig. 4 page 155)

EFFECT OF AIR: FUEL RATIO

The graph shows a set of curves which are typical of all gasolene reciprocating engines. Traditional engines have had Air: Fuel ratios around the "Stoichiometric" dotted line, that is, rich mixtures.

- The three-way catalyst equipped engine *MUST* operate at the stoichiometric point.
- The "fast-burn" engine operates around 16:1 Air: Fuel ratio. Examples are the latest 1984 VW Golf, the BL Jaguar V12 and the 1984 Ford Fiesta Valencia-built 1.1 litre.
- The "lean-burn" engine operates in the Air: Fuel ratio area beyond 18:1. Ford believes this is the engine of the future.

The most obvious feature is the low CO and NO_x in the "lean-burn" area. However, HC tends to rise, but can be controlled with careful combustion chamber design.

EXTRACT FROM THE INSTITUTE OF PETROLEUM MEMORANDUM

15. *Reduction in Automotive NO_x Emission*

The formation of oxides of nitrogen in an automotive engine is again essentially the result of the reaction at high temperatures of oxygen and nitrogen in the combustion air, the amount of NO_x formed depending on flame temperature and the availability of oxygen (i.e. Air: Fuel ratio). Fuel quality has little influence. Control and reduction of automotive NO_x has therefore to be applied to the car rather than to its fuel.

Controls are being put into effect by the various automotive manufacturing industries throughout Western Europe by successive engine design modifications to comply with the progressively tighter motor vehicle emission standards laid down under the series of amendments to ECE. Regulation 15 as mentioned earlier. (These regulate not only oxides of nitrogen, but also CO and hydrocarbon emissions.) Under the fourth and latest of these amendments, ECE 15-04, which has now passed into law and is applicable to all new 1984 models, and from 1986 to all car models under manufacture, there is a 20–30 per cent reduction in the combined levels for NO_x and hydrocarbon emissions from those set out in the previous ECE 15-03 requirement.

With the passing of new cars into the vehicular population now on the roads (estimated by the motor trade at the rate of some 15 per cent replacement per year) the progress will be ongoing.

The process of engine modification essentially involves a drop in flame temperature. This is achieved either by running with a richer fuel-to-air mixture, or by recycling of a portion of the exhaust gases. With either approach, there is inevitably some loss of performance and worsened fuel economy—for which a figure of five per cent has been quoted. Exhaust gas recycle can also be applied to diesel engines, with similar consequences. In all these cases, additional crude oil is needed nationally to offset the fall in engine efficiency and fuel economy.

The −04 level of regulation is held in some quarters to be close to the ultimate achievable by current engine modification—though this is disputed by developers of the so-called "lean-burn" engine. The motor industry sector is best qualified to comment on this. However, it may be noted that certain countries wish to tighten further the −04 level of regulation, adopting US-type catalytic exhaust converters to achieve this. Emission reductions of 80 per cent have been claimed for these converters, but the cost of fitting them to new cars has been quoted at more than £250 per car and the penalty in fuel economy as 10 per cent or more compared with the −04 standard.

US experience of these converters has not been encouraging; misuse during vehicle road life is said to have rendered many ineffective. High exhaust temperatures above 900° C sinter and destroy the catalyst, and it is thought that the smaller engines in European cars, driven harder on European highways, would more frequently produce such temperatures. Conversely, a minimum exhaust temperature of 300° C is needed to activate the catalyst, and this temperature is not reached in general European urban driving—which is where the accelerations that generate most traffic NO_x emissions are encountered. The effectiveness of catalytic exhaust converters remains to be assessed for European conditions.

It should be noted too that the principal objective of the introduction of the catalytic convertor in the US and Japan was to counter the formation of acutely lachrimatory and aggressive "PAN" type (peracetyl nitrate) smog concentrations generated by the inter-reaction of emitted nitrogen oxides and hydrocarbons under the climatic conditions and intense sunlight to be found in some areas of those countries—of which the Los Angeles basin and metropolitan Tokyo regions are prime examples. While such episodic occurrences are reported in areas of Southern Europe (eg Athens), it is not a significant feature in the differing climatic conditions of Northern Europe including Britain.

Examination of Witnesses

MR K B BARNES, Chief Engineer, MR T R ATKINSON, Chairman of the Petrol Engine Technical Committee, MR E J CUTTING, Chairman of the Car and General Technical Board and Chairman of Working Group on Energy, MR E W JOHNSON, Member of the Petrol Engine Technical Committee, MR J A WALLER, Chairman of Diesel Engine Technical Committee, of the Society of Motor Manufacturers and Traders Limited, called in and examined.

Chairman

325. Mr Barnes, may I welcome you and your colleagues to this public session of the Select Committee on the Environment. I am grateful to you for coming. I wonder whether you would care to introduce yourself and those who are with you.

(Mr *Barnes.)* Certainly, Mr Chairman, and we would thank you for the opportunity to offer evidence to the Committee. To introduce myself, my name is Ken Barnes, I am Chief Engineer of the Society of Motor Manufacturers and Traders and as such responsible for the technical services of the Society. With me today I have representatives from the four major companies, as requested, and I will go along the table in order. On my right-hand side I have Mr Jack Waller from General Motors or Vauxhall Motors, whichever way you like to look at it. He is also Chairman of our Diesel Engine Technical Committee. Next to him on my immediate right is Mr Cutting, who comes from Ford Motor Company. He is Chairman of our Car and General Technical Board and also Chairman of our Working Group on Energy, which looks at various pollution and energy matters so that it is all tied up together. On my immediate left is Mr Atkinson from Talbot, who is Chairman of our Petrol Engine Technical Committee; and on my far right is Mr Johnson from BL Technology, who is Chief Chemist for BL but does not hold any particular position within the Society. That is my group with me today.

326. Thank you very much indeed. I think that I can possibly save us all a certain amount of time by saying at once that the Committee does not want to trouble you with sulphur compounds, sulphur dioxide, and that aspect of acid rain. What we are concerned with very much is the effect of NO_x and hydrocarbon emissions from motor vehicles, because we have received a certain amount of evidence now in the course of our inquiry both in this country and overseas that forest damage can be attributed to ozone; and that NO_x and hydrocarbons which come from motor vehicles may be a contributory factor in that damage. We would like to test that evidence by asking you what your own experiences are and what your own research has led you to conclude, if you have in fact applied your minds to this particular problem in any way. So the first question I would really like to ask is what research, if any, has your association carried out into the possible effects of the emission of these two pollutants that I have just mentioned?

(Mr *Barnes.)* Simply, the industry in this country has not carried out any research on the relationship between these various matters. We believe there is a certain amount of doubt on the relationship and we believe actually that probably it is for other people to look at this relationship.

327. Very well. You have carried out no research yourselves but you believe there is doubt?

(Mr *Barnes.)* Yes.

328. Where do you derive your belief as to the fact that there may be a doubt?

(Mr *Barnes.)* Well, we have reviewed various reports and there seem to be differences of opinion between them. But I wonder whether perhaps I could ask Mr Johnson to comment on some of this. He is a chemist and understands the chemical relationship more than possibly most of us.

329. Certainly.

(Mr *Johnson.)* We have attempted in the Motor Manufacturers to do a similar thing to your Committee: review all the available evidence from the literature, and there is a great deal of conflict and even conjecture within this review. Every day you see people changing their minds as to the cause of various effects. For example, it only seems five minutes ago that the German press was full of acid rain tree damage definitely caused by acid rain sulphur emissions, yet this week again we read that the pendulum

[Chairman *Contd.*]

has swung to photo chemistry ozone damage, and as there seems very little scientific experimentation and data to show the real cause, there is a lack of scientific fact.

330. As you have relied on literature to reach the conclusions you have reached, what literature are you relying upon? The Committee has received a letter from BL Technology Limited in which they say they have not been directly involved in any research but have relied on published literature reviews, and then in the first appendix to their letter they give us five literature references. Can you tell me whether that is the extent of the literature that you, Mr Johnson, have also studied or whether you have studied any other literature as well?

(Mr *Johnson.*) We have studied over 100 sources of literature and we felt these were the most relevant of those 100 sources we have reviewed to the work of your Committee. We have talked with fellow scientists and engineers from other parts of Europe to gain an impression from their country and their work, and again there seems to be this reasonable doubt and lack of firm scientific evidence.

331. I am heartened by your saying you have studied 100 sources of literature because I think this is a very limited amount of literature set out in this letter and some of it that we have read does not really carry out particular inquiry much further. For example, one of those you gave is the report of Warren Spring Laboratories. We have had them here. All they are concerned with is the monitoring of the degree of various pollutants in the atmosphere. They have not carried out any research into the effects of those pollutants. So to that extent that is not a piece of literature which carries us much further on the subject under inquiry. If that was one of the sources upon which you relied heavily, we might well have come to the conclusion that even your literature was very light in information.

(Mr *Johnson.*) Yes. We have data searched by computer, and this is in fact our conclusion—that there is no real information on real studies of forest damage. There is monitoring and air quality data, but not a great deal of research into forest damage.

332. Well, you might get a surprise when you read our report in the summer!

(Mr *Johnson.*) Yes, indeed.

Mr Chapman

333. At the very beginning of your report, there is some uncertainty about the part played by NO_x in acid deposition. That is a very fair statement. There is no doubt the evidence we have got, particularly from our visit to Germany and Sweden, is that NO_x is a major source of ozone. What worries us is that we see the damage that is done to the Black Forest and we see the effect on many lakes and rivers and obviously a lot of damage is being done by acid deposition. It is a very worrying thing, but there seems to be a rather complacent attitude from the SMMT—I understand the uncertainty but not the complacency—and you come to the conclusion that it is a very minor part of acid deposition. I think the Chairman of BL Technology in his paper refers to the following: "Our main conclusion is that automotive sources are not major contributors to the formation of acid rain. We believe that the acidic components of the rain appear as 70 per cent sulphuric and 30 per cent nitric." etc, etc. Would you stand by those percentages?

(Mr *Johnson.*) Yes, that is the indication from the literature review that we have carried out and certainly was the split of the two acids talked about in the Royal Society meeting last year, which is a gathering of experts on the subject.

334. Would you accept that of the 30 per cent nitric contribution, about 25 per cent comes from vehicles?

(Mr *Barnes.*) I think if you look at the Warren Spring figures, they show that the figure is somewhere of that order. If I remember rightly, without checking, I think they gave 29 per cent for the total NO_x emissions, which if looked at against SO_2 as well comes out at some 8.9 per cent, but I believe that Mr Cutting from Ford would like to comment on that as well.

(Mr *Cutting.*) I have a little document and I have a number of copies to add to the Ford letter that came from Mr Toy. If the Clerk would like to have them later they are available. Let me read from a page on the automobile contribution. "If for the sake of argument the passenger car is considered a contributor to acid rain it is inevitable that NO_x would be the main agent. Of the total gases emitted from the exhaust of the average car the acid pollutant precursors form about 0.02 per cent, and of this small percentage only five per cent are sulphur based, while the nitrogen based gases

[Mr Chapman *Contd.*]

account for 95 per cent, that is 0.019 per cent of the total. Indeed, when the content of NO_x from the vehicle is compared to that derived from other sources it does not assume a very significant proportion. The total United Kingdom NO_x inventory (ie the theoretical emission from all sources, plant decay, power stations, etc,) accounts for about 30 per cent of acid rain, while the automotive contribution to this NO_x total is about 23 per cent. It therefore follows that the automotive contribution to acid rain is: 30 per cent × 23 per cent = 7 per cent. If we add the contribution from diesel road vehicles then this figure rises to nine per cent with a scatter of perhaps + or −two per cent due to possible errors in the emission inventories." What we are saying is of the worst case, our content of the acid rain is about nine per cent, and that is on an historical basis with the vehicle park that there is out there today, and you have to remember that only vehicles built since 1979 have had NO_x controls. Now, of the 20 odd million vehicles there are on the roads in Great Britain, not a very high percentage have been launched on the road since 1979, so most of the vehicles have uncontrolled NO_x. We are now in a position where NO_x is controlled and that nine per cent figure is falling fast. I would like to expand on that later.

(Mr Barnes.) That lastpoint is basically covered in the Warren Spring evidence under their table where there is a footnote which refers to the fact that these are based on constant emission factors and do not take into account possible changes in emission factors over the years. They are looking at in effect the fuel going into the engine and deciding that so much of it coming out is NO_x.

Chairman

335. If the situation is as you say it is, and NO_x emissions are not very high and such as there are do not constitute a serious problem, why is it the Germans are becoming so desperately worried about it and are going to take quite extraordinary measures in order to reduce the amount of emissions? In fact, I believe they are going to impose even stiffer controls on their vehicles than the EEC are suggesting. You shake your head, Mr Cutting?

(Mr Cutting.) Yes, Sir.

336. Perhaps you would like to respond?

(Mr Cutting.) Yes. I think the results of yesterday's elections indicate the concern of the German Government. There is a larger and growing vote for the Green Party, and so there are political considerations. The German Government's actions for January 1986 are not mandatory actions. They are purely voluntary. What they are proposing is to give as yet to be determined financial incentives to people who will purchase passenger cars which meet the United States gaseous emittance standards, and there have been various rumours about what those commercial inducements will be, and the most popular of those is that the purchaser of a vehicle which meets the United States standards will be able to recover about half of the VAT he has paid, about one year later, we understand, but it is purely voluntary and there will be no compulsion at all on the sale of motor vehicles and that is because of German adherence to the principles of the Treaty of Rome.

Mr Roberts

337. Could you explain why you feel that the forests in Germany, in Central Europe, are defoliating to the extent that they are whereas the forests in Norway and Sweden, in those Scandinavian countries that are affected by acid rain, the forests are only just beginning to show some damage, in fact, there is not a serious problem, as of yet, the way there is in Central Europe, if you take account of the fact that the acid rain depositions, which it is claimed come from power stations mainly, are falling in Scandinavia just as much as they are falling in Central Europe and, in fact, the acidification of lakes in Scandinavia is very very serious indeed as a result of acid rain? Do you think it may have anything to do with the fact there are more motor cars in Central Europe than in Scandinavia?

(Mr Cutting.) Quite honestly, I do not think I can answer that.

(Mr Barnes.) I think that would be a question to ask the Forestry Commission as to what they blame this on. We do not have knowledge on this. I have heard it suggested—just a suggestion—that there is some difference in the growing policy between the differing countries in that the Scandinavians tend to cut their trees at an earlier time than the people in Central Europe.

[Mr Roberts *Contd.*]

338. They blame it on NO_x emissions, certainly a lot of the Germans do and one of the things we were able to consider was the speed of motor cars. There are no speed limits on German autobans, cars go much faster and we were told that results in more NO_x emissions. We are also told that the density of motor car traffic in Central Europe as opposed to Scandinavia is something which has to be taken into account, that is one of the things we were told.

(Mr *Cutting.*) All of these things are hypotheses as yet because no-one has done any real research, at least to the best of our knowledge, and although Ford Motor Company in Britain and the other Ford companies in Europe have not conducted research into acid rain, nevertheless Corporate activities in the United States have looked at it, admittedly on a United States basis. These are all relatively new things. Attention was first drawn to the possibility that the motor vehicles could be producing NO_x as a precursor to acid rain a relatively short time ago; in research terms it is still far too early. The conflicting reports one gets are truly enormous.

Chairman

339. You are making sweeping statements. We will consider very, very carefully what you have to say to us in the light of evidence we have received from other sources, including this country, in Germany and Sweden and we are very well aware of the extent of the research going on in these matters. I take note of the fact that you feel that research has not made very much headway or is still inconclusive, the Committee will make note of that point. Do you know or are you aware of what proportion of ozone in the atmosphere can be attributed to motor car emissions?

(Mr *Cutting.*) Is that a question directed to me?

340. Yes?

(Mr *Cutting.*) No, sir, I am unable to answer that.

Mr Taylor

341. I would like to ask a question which is in some ways supplementary to what Allan Roberts was pursuing. I am wondering whether anything is known of the relationship between motor speed—or I suppose less naively, one should say the engine speed—what is known of the relationship between engine speed and NO_x emission? Is it a linear relationship, the more the more, one to one, or is it exponential? Is it possible NO_x emissions are substantially greater or disproportionately greater at higher speeds?

(Mr *Barnes.*) Can I ask Mr Atkinson to answer that.

(Mr *Atkinson.*) The highest emission of NO_x occurs at full throttle, maximum engine power and speed. It is a function all the way through the speed range right up to the top. There is no sudden break away at which NO_x becomes greater. It is a function of the amount of horsepower which the engine is producing.

342. It is important that the record should have this right, even if I am not a mechanical engineer, could you enlarge slightly more clearly, you have said the relationship to watch is not between engine speed and emission but the rate at which the engine is working; would that be the same as saying maximum torque or not?

(Mr *Atkinson.*) Maximum horsepower but it is linear it is not exponential.

343. Is it linear?

(Mr *Atkinson.*) Yes.

344. If that is so, I am sure my friend Allan Roberts will be entirely in sympathy with this question and would probably have put it himself, are we not true to say as general observers and laymen that the state of the German personal economy and the state of the German roads, for example, probably means that that country has got some of the hardest working engines anywhere in the western world?

(Mr *Atkinson.*) I would agree entirely with your remark but I must point out they are not operating at full throttle all the time.

345. I realise that.

(Mr *Atkinson.*) They are at that level some of the time. My remarks are related to full throttle, once you come away from full throttle then there is a reduction.

346. I have not got you wrong, Mr Atkinson.

(Mr *Atkinson.*) If you take the situation on British motorways where the maximum permitted speed is 70—quite a lot of people travel at 80....

[Mr Taylor *Contd.*]

347. And more.

(Mr *Atkinson.*) . . . that is still very much a cruise condition and a long way from full throttle operation.

348. Any motorway map of Europe—I ask you whether you agree with this or not—as a frequent European traveller myself, the motorway network from the channel ports to the Yugoslav border is impressive and complete, there are a tremendous number of hard working engines?

(Mr *Atkinson.*) Yes.

349. You agree?

(Mr *Atkinson.*) Yes.

Mr Roberts

350. It was said there is some control of NO_x emissions on cars coming on to the British market as from 1979, could you tell us what that is and how effective it is in stopping NO_x emissions and how does that line up with what the Germans are proposing particularly with regard to the fact the Germans fixed a specific date for their engines to go lead free?

(Mr *Cutting.*) As I explained earlier, Mr Chairman, they have not, it is a voluntary scheme. The Germans have not fixed a date for their engines to go lead free.

(Mr *Barnes.*) They have asked for fuel to be available but not all fuel.

Chairman

351. My impression was their Minister told us they had fixed a date?

(Mr *Cutting.*) They have fixed a date after which they want the oil companies to provide unleaded gasoline, not lead free.

352. We are talking of controlled NO_x emissions?

(Mr *Cutting.*) I see, I am sorry. I have a little chart here, it is the 15.03 legislation of the United Nations. It came into effect in 1979 and was the NO_x reduction step. There was an earlier step, 15.02 which came into effect in 1975 which was the first time NO_x was controlled. In 1975 NO_x was reduced—that is hydrocarbons plus NO_x was reduced—by 15 per cent. I have drawn it like *this* (*Indicating*) because the 15.04 legislation, which the United Nations brought into effect in October 1982 and which the European Community does not bring into effect until October this year—two years later—then the United Nations reduces it 35 per cent from the uncontrolled level. The proposal put forward by M d'Avignon and which is now the Common Market proposal is proposing to reduce hydrocarbons plus NO_x to 64 per cent from the uncontrolled level. That is the NO_x legislation information.

Mr Roberts

353. What does it do? How do you stop the hydrocarbons coming out? You do not go lead-free.

(Mr *Cutting.*) No, you do not need to.

(Mr *Atkinson.*) Up to now in Europe the primary aim was emission control. If you can put the emission at the optimum point you will produce the least NO_x. When further control is needed—and some vehicles will use this system to meet the 15.04 regulations—the use of inert exhaust gas bled into the induction system will affect the NO_x levels. Unfortunately one can only go so far. If you add a certain percentage, something like about eight or nine per cent, then it starts to affect fuel economy. So the use of exhaust gas recirculation into the system is pegged at 10 per cent, not more and this will slightly affect fuel economy. The next stage to that, I would prophesy, will be what we refer to as Fast-Burn or Lean-Burn engine, where the control is in the combustion chamber, which allows the engine to run on very weak Air: Fuel ratios. I think Mr Cutting probably has a chart which shows the effect when Air: Fuel ratio becomes weaker.

Chairman

354. Can we come to questions of practical control in a moment? There are still one or two points I would like to pick up from questions asked. Mr Taylor asked you a few moments ago a number of questions concerning speed of motor-cars and the emissions resulting from speed. Is there any distinction or would there be any difference in your answer between petrol and diesel engines at all?

(Mr *Cutting.*) Not really.

355. The answer you gave Mr Taylor would apply equally to diesel and non-diesel engines?

(Mr *Cutting.*) Yes.

Mr Roberts

356. Do diesel engines give off a lot of NO_x?

(Mr *Barnes.*) They do but generally it is lower.

Chairman

357. I wonder if I could come back to my ozone question. I asked Mr Cutting if the proportion of ozone in the atmosphere attributed to motor-car emissions, and you said frankly you were not aware. I think Mr Johnson was trying to catch my eye at that moment.

(Mr *Johnson.*) I was just going to refer to the ERGA, who investigated various aspects of motor vehicle pollution, and they studied ozone and it is one of the reports we referred your group to. Certainly the view of scientists from various Governments and industries was that there was a great deal of uncertainty that something like intrusion of the stratosphere ozone layer could cause an increase in ozone levels. They quote typical levels being 20 to 50 parts per billion, and that could rise rapidly to 100 parts per billion on these intrusions, plus photochemistry increasing it by two, but so little is known about that. I wanted to clarify that the vehicle industry itself does not produce measurable ozone at all from its tail pipe.

358. I accept that, but what troubled me, and it follows exactly on from what you have just said to us, is that the SMMT report or paper that has been submitted to us ignored the role of NO_x as a source of ozone and also ignored hydrocarbons altogether. Whilst we accept that the motor-car does not emit pure ozone, the evidence that we have received—and it is a little more definite than you understand it to be, let me assure you of that, from the scientists we have spoken to—there is a very clear nexus between the emission of NO_x and hydrocarbons and the increase of ozone in the atmosphere, all resulting in a great chemistry taking place with sunlight as the agent in the atmosphere. What troubles us, or is troubling me, from the evidence we are receiving this afternoon is that there is such a tendency to discount a connection between ozone, NO_x and hydrocarbons. Whether or not ozone is responsible for anything is another question. I would like to ask you specifically whether you see a connection between NO_x, hydrocarbons and the creation of ozone in the atmosphere.

(Mr *Johnson.*) I am sorry if you thought we were disputing that in any way, but it does take place. The photochemical reaction is well-known, well studied. The uncertainty we have in the motor industry is the role of the vehicle in that photochemistry. From our knowledge of the measurements we have made on our own vehicles. For example, we have measured methane levels in motor vehicle exhaust from seven to 20 per cent of the total hydrocarbons which is reported to be totally inaccurate in photochemistry.

359. Can I then ask you to make assumptions? I call them assumptions because I am not asking you to accept or admit these aspects. Let us assume that NO_x and hydrocarbons cause ozone to be created in the atmosphere. Then let us assume that ozone is a very significant agent in a lot of tree destruction that is taking place currently in the Black Forest. If that is the case then clearly the Germans are right in being concerned and in looking at ways of getting rid of motor vehicle emissions. Presumably if we are to sell motor-cars in Germany we will have to satisfy their market. Whether they vote Green or not it will become a marketing factor. Also if the idea catches on in this country it is something that the industry here will have to deal with as well—political or not. That being the case, how practically could we set about meeting that particular problem? How would you as motor manufacturers set about meeting that particular problem on the basis of all the assumptions I have asked you to assume for the purpose of this argument, because we have a range of options: we have catalysts, we have lean-burn and other ways of dealing with it? I would like to hear your views as to how you would like to be able to meet this problem if the problem exists.

(Mr *Atkinson.*) It really boils down, if you take your assumption to the logical conclusion, the goal should be no emissions at all. That is obviously not practical, so we would have to have a starting point of a certain level of hydrocarbon and NO_x. Again, if I can refer to the ERGA report, the various technologies and their capabilities in terms of emission control are well spelt out, as is their effect on the economy and costs. There are various levels of atmospheric pollution control equipment that can be added to vehicles. If I can put that in very general terms, the present levels at which we are operating at the moment mean that most people are not using engine

[Chairman *Contd.*]

control systems as such, no hung-on devices, other than perhaps exhaust gas recirculation. If we take it to the sort of levels which produce almost no NO_x, no hydrocarbons, then I think the three-way catalyst would be the only answer. That is the three-way catalyst with an oxygen pensor in the exhaust which would control the air : fuel ratio. That is the ultimate.

360. Somehwere in this evidence there is a statement to the effect that a three-way catalyst would not work on English cars because we do not get a high enough temperature burn. Is that right?

(Mr *Barnes.*) There are problems with this, yes. Certainly, taking into account the various technologies available, we do not necessarily believe that catalysts are the correct answer, when considering the use of this over the life of a vehicle. We have to really differentiate between two situations. You can have a good situation where you are taking a new car straight from production for checking, and you can get a very good situation using the three-way catalyst, but when you take the use of that vehicle on the road over its lifetime, there are a number of problems, one of which is temperature range within which the vehicle operates—not only the lower end, but the higher end. The other of course, is the malfunction of that catalyst. If you have a malfunction in the catalyst you could well be putting out raw pollutants. That is a very broad brush situation. There are a number of considerations. I think perhaps Mr Cutting can add to this. Perhaps I could mention that on Wednesday we are to make a presentation to the all party Motor Industry Group on this very subject, and we have some papers available on Wednesday which could be made available to this Committee.

361. When are you making this presentation?

(Mr *Cutting.*) 6.00 on Wednesday evening in this House.

362. You may find some members of this Committee there.

(Mr *Cutting.*) We would be delighted to have you.

363. Can I just ask you this: inevitably we come to cost, and a catalyst would cost what?

(Mr *Cutting.*) Between £450 and £500.

364. That would be added to the cost of the motorcar and you need lead-free petrol because otherwise you get clogged up, is that right?

(Mr *Cutting.*) Yes. It would poison the catalyst.

Mr Roberts

365. Can you put it on to an existing car?

(Mr *Cutting.*) No, you would need to re-engineer the car. You cannot fit a catalyst as an after-market fit to a car that has not been designed for it. The American companies will confirm this statement.

Chairman

366. Did you want to add anything to that?

(Mr *Cutting.*) I just wanted to say that you did ask me a specific question earlier about whether I knew about the ozone. I gave you a very specific answer, and that is because in the company that I am employed by we are not employed to make conjectural statements and so far as I am aware, every statement made about ozone in the atmosphere is conjectural and therefore I beg to give my answer as "No".

367. We are only here to test your knowledge, and you can only answer the questions as best you can. We then have to seek other sources of information where you are unable to supply it to us.

(Mr *Cutting.*) All I would say to you, Sir, is that anybody who can give you an answer which he or she alleges to be an accurate statement as to the cause of ozone in the atmosphere has to be treated with the greatest care, and so does the statement. If I could go to catalysts—the catalyst itself, although an expensive item, is by no means the end of the story. If you fit a catalyst to a car, you have to have a number of control systems one of which (the most important) is a device for ensuring that the amount of petrol against the amount of air burnt in an engine remains in a very very close ratio—about 14.7 to 1—give or take about 0.1 of a ratio. That means electronic controls. That is why we are talking of about £450 to £500. In Germany, the Government has accepted the trade association's figure of DM1,200 to 1,500. That price falls equally heavily on a small cheap car as it does on a very large car, so when we talk about £450 to £500 on a Ford Popular Fiesta, costing c. £3,500–£3,700, it is about a 14 per cent increase,

[Chairman *Contd.*]

but if we take a Ford Granada, of c. £13,000 we are talking about a five or six per cent increase, so you can see that the burden would fall most heavily upon the people who buy the cheaper cars.

Mr Chapman

368. Could I just take it a little further, because having gone to Johnson Matthey Chemicals to look at a catalyst and to talk to them about it I read with very great interest the evidence of the Automobile Association, which of course deals with this very interestingly. Can I first of all, on the catalyst, ask this: once it is put as part of a new car, does it last for the life of that car, or does it have to be replaced, or does the catalyst itself have to be serviced from time to time?

(Mr *Cutting.*) Everything depends upon the care which the owner of the car lavishes on it. You have to remember that the owners change as the car gets older. All the evidence from the United States (which is the only country with any documented evidence on catalysts) is that the first owners do take care of their vehicles. People who buy new cars by and large come from the somewhat wealthier—or people who have disposable income—section of the population. As cars get older, they move down the wealth scale, if you like, and the older the car the lower the disposable income of the person owning and operating it, until how cheaply the car can be run is the overriding factor in keeping and maintaining the car. What has happened in the United States is that leaded petrol is considerably cheaper than unleaded petrol, so the people with the older cars, the third/fourth/fifth owners, tend to use leaded petrol, and although something like 60 per cent of the cars in the United States now have catalysts, half of the petrol sold in the United States is leaded petrol. Once you use leaded petrol in a catalyst, you can say "Goodbye" to the catalyst, so owner care is the most important factor in the life of a catalyst.

Mr Roberts

369. Or not selling leaded petrol?

(Mr *Cutting.*) If you stop selling leaded petrol then the people who have vehicles that need leaded petrol would not be able to operate, and in the United States, of course, that is the majority of commercial vehicles. Commercial vehicles in the United States by and large below about seven tons are petrol engined. Would you agree with those figures, Mr Waller?

(Mr *Waller.*) I think your figures are acceptable. I would not argue with them.

(Mr *Cutting.*) The majority of the smaller commercial vehicles in the United States are petrol engine powered, so there is a demand for leaded petrol from that. It is relatively cheap. It is at least 10 cents a gallon cheaper than unleaded petrol. Don't forget that when and if we go to unleaded petrol in this country, there will be some 17 or 18 million vehicles out there in the field that run on leaded petrol and will be unable to change. Leaded petrol will have to be around for another 15 years and there will be this danger—that people will put leaded petrol in, and then there are other aspects of care. If, for some reason, the electronic controls break down or the exhaust gas re-circulation device fails to operate, generally speaking, the car gets a little more pleasant to drive, which does not exactly encourage the owner to go and get it fixed. The only way that you can ensure that catalyst systems remain at least halfway efficient is to have an annual inspection programme, and that annual inspection would take around half a day at the minimum, and if you really did the job properly you are talking about a day's work. I submit to you that there are relatively few people who are the third/fourth/fifth owners of cars seven to 10 years old who could afford to pay the bill to have their vehicle annually inspected on an inspection lasting between half and one day and then pay the bill to have it fixed, especially if a new catalyst costs £200 and that is a real price—retail, £200.

Chairman

370. As well as that capital cost, the AA have suggested in their evidence to us that there would be a power loss and a consequential increase in petrol consumption?

(Mr *Cutting.*) Yes, Sir.

371. Could you tell us something about that, Mr Cutting or Mr Atkinson?

(Mr *Atkinson.*) The power loss would be as a result of having to decrease the compression ratio to make the engine suitable to use the octane ratings of whatever the unleaded gasoline turned out to be. This could be lower than the present premium obtainable. There is also an effect on back pressure which again reduces the through put of air through the engine and reduces the

[Chairman *Contd.*]

power. I notice the AA quote 10 per cent, we think that is the absolute maximum, we think it would be less than that. There is, however, another aspect of catalyst use which relates to the present motor car, the average fuel consumption of present motor cars as produced in this country and in Europe at the moment. Over the years, fuel economy has become more and more important and manufacturers are using the weakest Air: Fuel ratios, modified combustion chambers and are now producing what we considered very good economic figures. If we have to go to the catalyst, the biggest loss in fuel economy is by virtue of the fact you have to operate the engine at stoichiometric, 14.7 to 1 Air: Fuel ratio compared to some which are 17 to 1 and the fuel loss would occur in that aspect of the engine not due to the catalyst being there but by virtue of the fact it has to run on stoichiometric Air: Fuel ratios as opposed to what we are using.

372. What would this cost the motorist extra?

*(*Mr *Atkinson.)* The consumption we feel it is something up to 10 per cent, nearer 10 than lower.

Mr Alexander

373. Is the loss of power to which you refer, loss of power when accelerating from low speeds or from the top end when you are trying to go as fast as you can?

*(*Mr *Atkinson.)* Right throughout the torque speed range, it would not be very big, one whole compression ratio costs at the most 10 per cent. I think that would be as much as you would expect to lose and not knowing what the octane members of the gasoline would be, it is hard to know how much you would go down on the compression ratio. We do not look at the effect on performance as critically as we do on the effect on consumption.

Chairman

374. Mr Atkinson, I am grateful to you and Mr Cutting for that explanation of the catalyst, it is quite a formidable step to take. You postulate the catalyst as the only means of removing all emissions of these pollutants in ideal circumstances, are there any other methods we could use that would not achieve the same degree of removal as a catalyst but which we should consider?

*(*Mr *Atkinson.)* If you remember, Chairman, my answer was relating to your assumption that we want to get as much out as possible?

375. That is right.

*(*Mr *Atkinson.)* I think my colleagues would agree the three-way catalyst would be the ultimate.

*(*Mr *Barnes.)* You said about removal completely, even the catalyst would not remove completely.

376. That is the method of removal of the most possible?

*(*Mr *Barnes.)* Yes.

*(*Mr *Johnson.)* The point I think we ought to make the Committee aware of, there are adverse consequences of using catalysts if not correctly engineered. Learning from US experience, you have to carefully tailor the catalyst to make sure you do not get sulphuric acid aerosol or hydrogen cyanide or aldehydes. There are many other species produced by a catalyst working incorrectly that are not present in the first place. One has to clearly look at the environmental impact, one species for another. I want to make you aware it is not absolutely good news that they do not eat everything in emissions, they do create their own emissions. Platinum is another example.

377. As they do not remove all the pollutants we are concerned with at the moment, what percentage of NO_x and hydrocarbons would the effect....

*(*Mr *Atkinson.)* If you look at the present American market, they are losing about 90 per cent.

*(*Mr *Cutting.)* Everything depends on the test cycle. You must remember any test cycle is to some extent artificial. The way vehicles are driven in the real world, does not even approximate to a test cycle. On test cycles, the United States test cycles used, I suppose, somewhere around 95–97 per cent of the NO_x has been removed.

378. And hydrocarbons, do they deal with hydrocarbons as well?

*(*Mr *Atkinson.)* Yes, probably better than 90 per cent of the hydrocarbons. This is in the handout I have given to the clerk. The stoichiometric point is 14.7, right at the peak of the NO_x curve. When you have a catalyst, you set the engine to produce the maximum amount of NO_x so the catalyst can eat it up. Maybe this is the right time to lead into a description of Lean-Burn engines?

[Chairman *Contd.*]

379. I wanted to establish as far as I could what the catalyst can achieve and having established that then to ask you what alternatives are there to the catalyst and what are they capable of achieving and what cost? That leads us naturally into Lean Burn, would you like to address us on that?

*(*Mr *Cutting.)* First of all, when we talk about a Lean-Burn engine, we are talking about the way the engine burns petrol in relation to air. The more air you have, the leaner the engine and of present day engines, and there is the Jaguar V12, the Bedford CF van, the Ford Fiesta 1100 cc engine, the Ford 1.6 E-Max Sierra, Volkswagen Golf, all of these engines are what we call Fast-Burn engines. They are the first generation of Lean-Burn engines. The NO_x curve is falling somewhere around the 16:18:1 Air:Fuel ratio at the moment.

380. Could I interrupt you there, you have described lean burn as meaning the highest mixture of air?

*(*Mr *Cutting.)* Higher than 18:1.

381. What does fast burn mean?

*(*Mr *Cutting.)* It is the first step. It is a name that quite honestly.... We, in our company, have decided to call engines with 16:1 and 18:1 ratios fast burn for lack of a better word. In order to run an engine on that ratio you have to burn the mixture as quickly as possible within the combustion chamber. If you do that, if you burn the mixture as quickly as possible, in a rich mixture you would have a lot of NO_x but because you have surfeit of air, the temperature is lower. NO_x is a function of the temperature of burning in the combustion, the higher the temperature in the combustion chamber, generally speaking the greater the NO_x. Lean-Burn engines have lower NO_x. They have a lot of air and burn at a lower temperature.

382. If you are running at a lower temperature and less petrol, you are making economies?

*(*Mr *Cutting.)* You are making very big economies.

383. So what are the objections to going into Lean-Burn/Fast-Burn engines as soon as possible? It would advantage the motorist, quite apart from pollution problems.

*(*Mr *Cutting.)* There is a learning curve. Nobody yet markets a Lean-Burn engine and to the best of my information it will be three or four or perhaps five years before we see a number of them from a number of different manufacturers. The engines that I enumerated just now are all first generation Fast-Burn vehicles which are pointing the way. We are going to see a growth, I believe, of these Lean-Burn engines from all the manufacturers. The ERGA group pointed this out in their report and I believe that the Common Market Commission's proposal for their 1989 reduction levels can be met by Lean-Burn engines, at least in the light and medium weight vehicles, which is up to about 1250 kgs possibly. Over that we may have to go to catalysts.

384. So we have comparable answers as regards the catalysts. Will these Lean-Burn engines add appreciably to capital costs of your motor vehicle?

*(*Mr *Cutting.)* To the best of my information we are talking about sums of money less than £100, possibly of the order of £50.

385. So you pay a little more for your motor-car and you will then run it much more cheaply because you will not need so much petrol?

*(*Mr *Cutting.)* Precisely.

Mr Taylor

386. I do not know if this point has been covered, but I rather share with you the conclusion that if so many factors seem to point in this right direction one wonders what is the inhibitor stopping everyone making speed that way. I as a layman must ask you, are there any other penalties in all this—any disappointments, any discouragements, to hastening down the road of fast burn, lean burn? Could it be that the cars will perform less vividly?

*(*Mr *Cutting.)* No. Could I try and answer that question, Mr Chairman, if you would bear with me a moment, by touching on what is meant by this lean burn and fast burn. You are probably aware that when the piston comes up and compresses the air the petrol vapour or petrol droplets are mixed up with it. If you have not got a lot of petrol in there the dispersion of those droplets is much wider than it is if you have a richer mixture, and one of the difficulties most of the research has been aimed at is organising a system within the combustion chamber that guarantees that you burn all that fuel and you burn it quickly. The basis of this research is turbulence, so that if you can achieve a situation at the top of the

[Mr Taylor *Contd.*]
compression when the spark plug fires the flame the propagation is almost instantaneous.

387. That is a more effective bang?
(Mr *Cutting.)* That is right, a much bigger bang. In terms of performance it will be at least as good, and possibly better, because we hope that we will be able to use high compression ratios. So nowhere are there any inhibitions in terms of performance.

Mr Chapman

388. That is damning evidence against the catalyst but it is widely used in the United States. Why is that? Are they completely wrong?
(Mr *Atkinson.)* This is the only way to meet the sort of levels that they talk about.
(Mr *Cutting.)* When they started and decided they had to go to these very low levels it was the only technology available. The Lean-Burn engine is the product of research work begun in the 1976 to 1978 period.

Mr Roberts

389. It is the difference between the amount the catalyst system takes out and the amount a Lean-Burn engine takes out. How much NO_x will the Lean-Burn engine be taking out?
(Mr *Cutting.)* A fair amount less than the catalyst.

390. What does that mean?
(Mr *Cutting.)* Two to three times.

Mr Chapman

391. Could you repeat that?
(Mr *Cutting.)* Two to three times.

392. More NO_x?
(Mr *Cutting.)* When we have a catalyst on the test cycle—only on the test cycle; in the real world the answer could be the same—you can get down to something like 0.7 grams per mile, that is the US test cycle NO_x. The Lean-Burn engine will be something like 1.5 grams per mile on the test cycle.

Mr Roberts

393. So you are reducing NO_x by how much by going lean burn?
(Mr *Cutting.)* Of the order of 80 per cent over the uncontrolled.

Chairman

394. So we are talking about a difference of 80 per cent and 97 per cent between the two systems?
(Mr *Cutting.)* That is the worst against the best.

Mr Chapman

395. You have explained the disadvantages of the catalyst pretty graphically, if I may say so. Quite apart from what you have said in the AA evidence, you also mentioned about the core of the catalyst having to be at a certain temperature, not less than 400 degrees, not more than 900 degrees, ideally 600 degrees. In the stop/start motoring in the metropolis and other cities the catalyst would tend to be too cold and if you were doing a long journey fast on a motorway it would tend to be too hot.
(Mr *Cutting.)* Yes.

396. Is there any scientific evidence as to how that reduces the effectiveness of the catalyst? You have mentioned the ideal test conditions and in the real world people do not drive like that, but are there any statistics you can give us to say that Mr Average Person in his average car with the average miles he does would tend 50 per cent of the time to have the core of his catalyst at either too low or too high a temperature?
(Mr *Atkinson.)* In the first place you have to find an ideal point to place your catalyst so that it gets high enough to deal with the emission cycle. If someone drives a car below the emission cycle—and I do not think he would be too popular—it would not get very high and it would not operate because the thing starts to come alive, it becomes activated as a catalyst at somewhere around 300 and quite quickly moves up to, say, 95 per cent conversion, at which it stays fairly level until it reaches temperatures at which the whole structure of the ceramic monolith on which the catalyst is mounted starts to melt and then there is a failure of the catalyst. In order to avoid that sort of thing it may be necessary, particularly with small European engines, to put some sort of cut-out in the system that will bypass some of that exhaust in the conditions of very high speed—autobahn running at full throttle. Under these circumstances again you would be in a relatively uncontrolled situation. I think it is fair to say that not enough development work with catalysts in European conditions has been

[Mr Chapman *Contd.*]
carried out to be able to say in broad terms that we can put catalysts on small European cars. Certainly the knowledge is not yet there to be able to put a catalyst in and guarantee that it will be there 100 per cent of the time and be fully operative under any conditions.

Chairman

397. Just one other question on lean burn: you have told us about 80 per cent reduction in NO_x. What in hydrocarbons? I do not think we got that figure.

*(*Mr *Cutting.)* From the 04 level, which will be some 60 per cent from the uncontrolled level, not very much, but you must remember that the 04 level, which has not yet come into effect, is measuring all of the hydrocarbons. The 03 level currently measures only the methane, does it not?

*(*Mr *Johnson.)* No, well, there is a change in measurement technique which changed the effective level of total hydrocarbons by a factor of approximately two, so the measurement technique introduced in the new procedure gave double the results on the same car than by the old procedure, so you have got to take that into account when you look at the reduction. You have done that on your chart....

398. Yes, but from all that science, can you just give me a simple figure?

*(*Mr *Cutting.)* The Lean-Burn engine is unlikely to give us very much of a saving on hydrocarbons.

399. That will remain a problem, therefore, will it?

*(*Mr *Johnson.)* The change in technique was that total hydrocarbons historically were measured by means of infra-red gas analysers, which did not measure everything coming out. They measured largely paraffinic species. We have changed the technique to a flame ionisation detector which does not miss anything.

*(*Mr *Cutting.)* That technique does not come into general use in Europe until October this year. We carried out some exercises. We know it doubled the number of hydrocarbons.

Mr Alexander

400. The AA indicated, I think, that there are side effects with the Lean-Burn engine and I think Mr Johnson mentioned it too of hydrogen cyanide.

*(*Mr *Cutting.)* That is with the catalyst.

401. What is HO then?

*(*Mr *Johnson.)* That is hydrocarbons.

Mr Alexander: I am sorry. I should have checked up. I shan't pursue that question.

Chairman

402. Is there any method that is being explored for the removal of hydrocarbons as an alternative to the catalyst?

*(*Mr *Cutting.)* We are hoping that a device which is known as an "oxidation" catalyst could be coupled to a Lean-Burn engine eventually, for the express purpose of dealing with the hydrocarbons. Now there seems a chance that it might be possible to make a catalyst from other than noble metal, which would do that, but it is probably 10 years away. One of the problems with catalysts today is that they are made from noble metals—platinum, palladium, rhodium—and the world's supply is undoubtedly adequate for the people who currently use them, the Americans and Japanese, but one wonders what would happen to the price of platinum, palladium and rhodium if 10 million cars in Europe started using them, and of course the source, other than Soviet Russia, is almost wholly South Africa, and the principal source even then is really one mine—the Rustenburg Mine. The western world therefore would be very heavily dependent upon South Africa and within South Africa on one mine, which is rather a sobering thought as a supply source.

403. So then, to sum up what you have been saying to us this afternoon, if NO_x hydrocarbons have this effect that it is being said by some people it is having upon forests, and which I understand you do not accept or admit, nevertheless you say to us if we were patient, in five years' time, a Lean-Burn engine/Fast-Burn engine would be sufficiently developed which would remove a very high proportion of this particular problem without our having to go into an immediate expense of £450 per motor car using noble metals in short supply from South Africa and increasing the fuel consumption to the motorist. Does that sum up your evidence to us this afternoon?

*(*Mr *Barnes.)* Yes, I think that is a fair summary, Mr Chairman.

Chairman: Thank you for your attendance. This we have found very helpful indeed. Thank you.

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WEDNESDAY 20 JUNE 1984

Members present:

Sir Hugh Rossi, in the Chair

Mr Richard Alexander	Mr Robert B Jones
Mr Sydney Chapman	Mr John M Taylor

ACID RAIN

CBI Evidence to House of Commons

1. We attempt in this paper to answer the various aspects of the "acid rain" issue which are raised by the Inquiry's terms of reference. We have already given evidence to the House of Lords in relation to their Inquiry on EC Air Pollution policy, and the main paper is attached because of its relevance to this study. The CBI itself does not undertake technical research, although it has access to the studies and findings of its members: our comments seek to give an overall industrial picture, leaving particular sectors, as necessary, to spell out in detail the matters of special concern to them.

2. We accept there is an "acid rain" issue to which attention must be given not only in relation to the environment but also in respect of energy policy. We fully endorse the considerable resources committed to research in this field; some £1.8m by Government for 1984–85; a £5m project sponsored by the NCB and CEGB, in conjunction with the Norwegian and Swedish Royal Societies; and numerous other studies in industry and research establishments. Research should continue to embrace not only the environmental impacts and their causes but also fuel treatment, emission abatement technology and environmental impact reduction techniques. Greater knowledge is an essential prerequisite to dealing with this complex issue, and much resource should be allocated to getting it.

3. Further, there has already been significant reductions in the emissions from industrial plant (eg more than 30 per cent in SO_2 levels over the last decade), much due to the more efficient use of energy. UK energy policy should be framed to continue this trend.

4. We do not believe it wise to embark hurriedly upon a couse of legislative actions, even though some other countries have done so; there is a real possibility that their actions would be inappropriate and ineffective and would divert valuable resources from more legitimate claims. We will show, later, that the monies involved can be substantial, annually equal or more than the UK's desired payment to the Common Market. We contend that it is possible to achieve a more certain effect at considerably less cost, even in the absence of the research results necessary to throw more light on the many scientific and technical uncertainties.

5. The Inquiry has several strands:

(a) the emission, transmission and deposition of pollutants;
(b) their environmental effects;
(c) possible control strategies;
(d) possible control technologies; and
(e) costs.

It should, in our view, consider the full range of phenomena contributing to environmental acidification.

The cost of printing and publishing these Minutes of Evidence is estimated by Her Majesty's Stationery Office at £1,500.

A. EMISSIONS, TRANSMISSION AND DEPOSITION

6. Acidity, measured on a pH scale, derives from natural and man-made sources. Rain is naturally acid—water in equilibrium with atmospheric carbon dioxide has a pH of 5.6 which is reduced further by other natural processes (for example lightning flashes in the upper atmosphere producing nitric acid, volcanic and biogenic activity giving sulphuric acid). In the absence of anthropogenic emissions, precipitation pH would vary between 4.5 and 5.6 due to these natural emissions alone. In the UK the pH of rain varies from 4.1 to 4.7 although more extreme values have been recorded.

The pH of rain is not very significant in terms of ecological effect as compared with the total deposition of sulphate and nitrate which is associated with it.

(i) *Emissions*

7. Much of the acid in the air is formed from sulphur dioxide (SO_2) and nitrogen oxides (NO_x), some 50 per cent and 75 per cent respectively of which occur naturally throughout the world. These figures are lower—but still significant—in Northern Europe. There are several sources of SO_2 and NO_x many of which are natural and which contribute substantially to atmospheric concentrations. In the case of NO_x, neither the sources nor the fate of emissions are certain. The man-made contribution comes to a large degree from the combustion of fuels (90 per cent of the SO_2 and 50 per cent of the NO_x). Warren Spring Laboratory give the following UK sources in 1982:

SO_2		NO_x	
Power stations	66%	Power stations	46%
Refineries	5%	Road vehicles	29%
Other industry	19%	Commerce and industry	19%
Domestic	5%	Domestic	3%
Commercial/public sector	4%		

These figures can only be approximate. The accuracy of values for NO_x is much less than those for SO_2.

8. For the UK the trends in the amounts emitted are downwards for SO_2 and constant for NO_x:

SO_2 5.64m tonnes in 1972, 4.04m tonnes in 1982 (−28%)
NO_x 1.73m tonnes in 1972, 1.67m tonnes in 1982 (−4%)

the result primarily of gas and electricity use by domestic and commercial consumers, increased coal-burning in power stations, and the recession. Also increased industrial efficiency and stringently-enforced pollution controls have played a part. Generally, the UK record of abating air pollution is good.

(ii) *Transmission/Deposition*

9. Deposition of acidic materials occurs in either the dry or wet state:

"Dry" deposition is understood to be the direct adsorption or impaction of atmospheric species (SO_2, NO_2, sulphate or nitrate) on land and plant surfaces and occurs in the absence of rain; it is directly related to the atmospheric concentration of the species involved and hence declines with distance from the source of emission. In the UK 2/3rds of SO_2 is dry deposited.

"Wet" deposition is the deposition of acidic species in water droplets as rain, snow, cloud impaction etc. It is enhanced by the conversion in the air of some SO_2 and NO_2 to sulphate and nitrate (reactions the rate of which depends on a supply of photochemical oxidants, such as ozone) and a lack of neutralisation or dry deposit en route. Most areas with high acidic deposition totals distant from source are those with high rainfall frequency eg Norway, West Scotland.

Eighty per cent of total (wet and dry) deposition in the UK is due to indigenous emissions.

Overall the amount of acidic material from a particular source deposited per unit area declines sharply with distance from the emission source. Only a small fraction is deposited on sensitive areas outside the UK eg only 2 per cent of UK emissions are deposited in Norway (18 per cent of Norwegian total deposition).

The processes are complex and the science far from clear. The relationship between emissions and deposition is uncertain and it is highly unlikely that a reduction in emissions will give a pro rata reduction in deposition. Considerable study and modelling is needed to find out about the mechanisms involved so that future plant design, including chimney height, can be optimised in terms of environmental impact.

B. EFFECTS

10. Acid deposition clearly has a number of potential environmental impacts although the evidence of damage is far from conclusive. These are:

(*a*) *Lakes*

Although direct deposition on lakes will serve to lower the pH, the contribution and effects will be small compared with the indirect inputs from drainage of the catchment area. The main components of soil to be affected by acid deposition will be calcium and magnesium (which offer a degree of neutralisation) and the relatively more toxic aluminium (which may be converted into soluble form and pass into drainage waters). The processes and their effects will be determined by a number of factors: the acidity of rain, the rate and amount of drainage; the concentration and availability of these substances in soil and water. Forest cover is important: forestry enhances drainage, trees may take up calcium and magnesium from the soil and may increase the acidity of water droplets reaching the ground. The common (but not consistent) characteristics of ultimate damage, fishless lakes, are low pH and high aluminium content.

Unfortunately the relative importance of the factors determining lake damage are unclear and sometimes conflicting. Acidic soils such as those in certain Scandinavian regions are often deficient in calcium and magnesium; but it has been shown that even in 1 mm depth of acidic granite there is sufficient calcium to "neutralise" 200 years worth of acid rain at pH 4.3. Fishless lakes existed before the industrial revolution and some now occur above the tree line. The only current conclusion is that the physical and chemical reactions leading to the death of lakes are neither clear nor predictable.

(*b*) *Forests*

The effects on forests are even less defined. There are real doubts whether acid deposition is a significant factor in forestry damage and whether controls over SO_2 would help at all except where it is known that there are direct phototoxic effects. Hence forestry damage should be considered in a different and separate context.

The damage claimed often occurs in high-elevation forests (over 600 m above sea level) and erratically even within one species. Deficiencies of soils, climatic stress (eg after the 1976 drought), forestry management practices, forest growth itself, and a combination of ozone and acid mists are all suggested causes: current evidence suggests that ozone levels may be the single most important air pollution factor.

(*c*) *Crops*

The uncertainties associated with forests apply equally to crops. In areas of sulphur or nitrogen deficiencies in soil, acid deposition can be beneficial. Evidence shows that there are no adverse effects on crops where SO_2 and NO_2 levels are typical for suburban situations. Ozone levels are again important and may be responsible for any observed damage.

(*d*) *Buildings*

Attempts have been made to cost building damage to acid deposition: these are misplaced. Where atmospheric damage of buildings occurs it is limited (to stonework) and results mainly from local emissions—from traffic, houses and commerce. Natural weathering and frost are also highly significant. The damage has been gradual over a long period of time.

(*e*) *Health*

There is no evidence that ambient levels of SO_2 and NO_2 have any adverse effect on public health.

11. The overall conclusions is that the relationship between the observed and environmental effects of "acid rain", and the role of other factors, is very uncertain and will not respond to simplistic solutions. Published costs of damage attributed to acid rain are confusing. For example in its explanatory memorandum to the proposed directive on large combustion plant (COM(83)704) the EC Commission's estimate of damage may be four or five times that suggested by the consultant's report on which it is based. Cost data must be considered with all the caveats, and in context.

C. POSSIBLE CONTROL STRATEGIES

12. The urgent need is for a clear framework of air pollution policy throughout the European donor and receptor area, elaborated for individual countries. Within this framework, consideration of future controls should weigh the advantages of actions aimed at:

(a) local or long-distance effects;
(b) the EEC or pan-European countries;
(c) prevention or cure;
(d) major or all emitters;
(e) new or existing installations;
(f) one or more named pollutant;
(g) air or other environmental media.

Respectively:

(a) Historically, the major impact of emissions has been *local*, a basic fact from which any environmentally-sound control strategy should start. In this respect UK air pollution controls have been very successful (witness the virtual elimination of London smogs and the decrease in UK emissions to pre-1940 levels). Enforcement of existing legislation with its in-built scope for further improvements will preserve the good condition of the UK's atmospheric environment. However, long-distance effects have now been recognized and these may require an alternative solution.

(b) From 1973 to 1978 emissions of SO_2 from Eastern bloc countries increased by 40 per cent; in 1980 they emitted 33 m tonnes of SO_2 from a European/USSR total of 58 m tonnes. To consider emission reduction targets in an EEC but not pan-European context is illogical and if this approach were adopted it would be ineffective.

(c) If the desire is to deal with long-range transfrontier air pollution, two approaches might be considered:

(i) *Preventive*

This relies on a fairly precise understanding of the relationship between source and receptor. At the current time there is insufficient knowledge to develop a cost-effective preventive approach. Consequently any action will be speculative and highly dubious in terms of effectiveness. For example, Japan has so far failed to achieve desired reductions in atmospheric NO_2 levels by acting against man-made emissions of NO. The lessons of the Japanese experience should be heeded.

(ii) *Curative*

Curative methods of dealing with the effects of acidification, from whatever cause, are more readily apparent. The most obvious is the use of liming of lakes or water catchments of forests. This should be relatively simple, although more development of effective and appropriate methods of application to a variety of locations is still needed. The cost should be reasonable and the chances of success high. More supportive work on the chemical balance in lakes is also needed. This approach has several advantages:

—it could be instituted relatively quickly and cheaply;
—it would provide time to eliminate some of the uncertainties in the costly preventive approach;
—by eliminating the effects of acidity, the role of other causative agents would become better defined.

(d) If it is necessary to reduce total national emissions of SO_2, it is most cost-effective to concentrate on the very large combustion plant because of the ease and feasibility of accommodating the necessary changes. However, such controls will not have the optimum cost–beneficial impact on many effects within the UK (eg corrosion) which are the consequence of low-level sources.

(e) It is far cheaper and more efficient to programme lower emission targets in the original design of industrial plant. Retrofitting is at best very expensive and may not be a viable alternative, for want of space or finance. The cost is also enhanced because of the shorter, remaining life of the plant. Further a substantial (five year) redesigning/rebuilding programme may be needed.

(f) The effectiveness of any control strategy will be determined by the choice of the pollutant(s) for priority action—how dominant it is in the problem under investigation; how conducive it is to control; what controls have already been exercised; and the availability and efficiency of suitable control techniques. Most of these parameters have still to be evaluated.

(g) Action against one environmental problem may create others: the desiderata is the "best available environmental option". For flue gas desulphurisation, a number of processes are possible. On a single 2000 MW power station one process will consume each year 270,000 tonnes of limestone and discharge 350,000 tonnes of sludge (calcium sulphate and chloride); another would use 310,000 tonnes of limestone to produce 230,000 tonnes of sulphuric acid and 100,000 tonnes of sludge (sodium sulphate and calcium chloride) for disposal on land. Obviously these quantities of materials will be difficult to handle, creating environmental problems in their extraction, movement and final disposal. There could be limited outlets for some by-products but the economics are unfavourable and problems with some constituents would have to be solved first eg trace elements may prevent setting of cement.

D. POSSIBLE CONTROL TECHNIQUES

13. A number of options are available, although the scope for dealing with NO_x is extremely limited because of the considerable contribution from undetermined and natural sources and the lack of suitable technology to reduce emissions from UK industrial sources. Most of the options will require extra time and research to be practicable:

(a) *Plant closure or location elsewhere*

May be the only option if extra costs of reducing SO_2 levels make process unprofitable or if space to accommodate treatment plant is not available.

(b) *Fuel Switching*

The options here include a distinct increase in the nuclear component (as the Royal Commission on Environmental Pollution suggests); greater use of natural (and substitute natural) gas; importation of low sulphur coals (from Australia or America); or use of low sulphur crude oil (eg North Sea). All pose political choices. In addition there will be competition (and a premium) for desired fuels, according to their availability.

(c) *More Energy Conservation*

A developing trend in the UK industrial sector which will continue and which will in the longer term contribute significantly to the reduction of emissions.

(d) *Modified Combustion Processes*

Fluidized bed combustion (FBC) is now a commercially available option for some small, routine plant but is not proven in many situations. Further research is necessary to scale up to larger units. The NCB and CEGB are cooperating in research and development of pressurised FBC; results are promising with up to 90 per cent sulphur being retained and NO_x levels being 40 per cent below those expected from traditional firing. The project is long-term.

(e) *Pretreatment of fuels*

NCB coal as supplied to CEGB (70 per cent of UK coal) is a blend of two thirds washed (coarser) coal and one third unwashed (finer) coal. Scope for reducing SO_2 emissions by further washing is very limited and very expensive. Half of the average 1.5 per cent sulphur in UK coal is structurally linked and commercial techniques to remove it do not exist. The 1.5 per cent nitrogen content cannot be physically separated and in any case is not the sole source of nitrogen for NO_x formation. Fixation of nitrogen in the combustion air also produces NO_x.

(f) *Flue Gas Scrubbing*

Flue gas desulphurisation are reasonably well-established techniques, but are costly and pose environmental problems in terms of space required, limestone consumed and wastes produced.

(g) *Treatment of affected lakes/catchment areas*

Can cure the symptoms and give rapid responses at comparatively low costs. It will give time for a better understanding of the overall problem and the development of appropriate long-term solutions.

(h) *Variation of Forestry/Agricultural Practices*

Traditional forestry practices (eg mass planting of conifers in upland drainage basins) and agricultural practices (eg fairly recent discontinuation of liming) contribute very largely to the observed soil and lake acidity. Variations in farming and forestry practice may help overcome the problems without affecting yields. More information is needed.

E. COSTS

14. We cannot put precise costs—financial or jobs—to all the control options mentioned in the earlier section: suffice it to say they will often be severe. However we wish to record several impacts.

15. OECD puts the cost of removal of SO_2 at about £250 per tonne for new plant. This is a considerable understatement for existing plant with their shorter lifetimes: a figure between £440 and £740 per tonne is more appropriate. Since in the UK it will be mainly existing plant affected, at 1980 levels the annual cost of reducing UK emissions of SO_2 by 60 per cent would be at least £1500m. This should be contrasted with an annual cost of liming the Swedish lakes claimed to be effected by "acid rain", estimated to be £20m. Further, in terms of solving an environmental problem, SO_2 removal may be an abortive expenditure.

16. The financial penalties on industry of additional *emission* controls are both direct and indirect:

(a) *Electricity Costs and Prices*

For a 60 per cent reduction by 1995 of CEGB's SO_2 emissions (1980 levels), a capital outlay of £1500m to retrofit twelve power stations is required. 660 MWs would be lost to the system and cost £500m to replace. The annual operating cost increase (from 1995) would be £350m. The resulting increase in electricity generating cost would be in the region of five per cent and the increase in price to industry would be even higher with the existing tariff structure. There would be considerable additional costs to reduce NO_x emissions but in the absence of technology suitable for adoption by present UK power stations these cannot be fully quantified.

Certain intensive electricity consumers are already at a competitive disadvantage via-a-vis EC competitors, despite the UK's comparative wealth in fuel resources. Any price increase could further jeopardise competitiveness.

For the *cement* industry, the cost of electricity is about eight per cent of delivered price and another increase at this time could be particularly severe, with non-EC producers making a real attempt to gain a stake in the European, and especially the UK, markets. The *chemical* industry would incur an additional annual electricity bill of £34m (they paid £450m in 1983). All parts of that industry would not be effected evenly, but for those activities for which electrical energy represents a major cost input (eg over 50 per cent of total cost in the case of chlorine manufacture) the impact would be severe.

(b) *Other Emitting Industries*

We estimate the capital cost of fitting new plant at other industries to reduce SO_2 emissions, to be:

Cost per kw	*Plant thermal outputs*
£200	50–100 MW
£130	100–300 MW
£65	300 MW

The impact of direct reduction targets varies from industry to industry, from company to company.

In the *glass industry* there are about ten plants of 50 MW and above heat capacity, fired by natural gas. Technically the means to achieve 40 per cent reduction in NO_x levels does not exist, so the costs are unquantifiable.

For eight sites in the *textile industry*, with multiple boiler units and varying capacities, reduction of SO_2 emissions by 30 per cent would involve a capital cost of £25m and annual operating costs of £18m—burdens too high for the industry to accept and remain competitive.

The *chemical industry* has some 80 plants of 50 MW or above; the *oil industry* 17 refineries, and maybe five times as many individual plants within these refineries, above this level. Clearly direct emission reduction limits will have major financial implications.

(c) *Mining, Waste Disposal etc. Industries*

The use of flue gas desulphurisation (FGD) would necessitate more mining and transport of limestone to satisfy demand. It places a heavy demand on waste disposal facilities. For potentially usable end materials current markets could be over-saturated and the supply industries destroyed. Thus for *one* 2000 MW power station, using two per cent sulphur coal, the products of FGD in relation to present UK consumption are:

Sulphuric acid	8%
or Sulphur	8%
or Gypsum	11%

To retrofit on twelve stations, the potential impact is severe.

(d) *Oil Industry*

(By removal of sulphur from heavy fuel oils (residual desulphurisation)):

The costs of removing a tonne of SO_2 from heavy fuel oils are:

Capital	£680–£1,585
Operating (annual)	£300–£641 (including annual capital charge)

The costs of removal depends on the range covered ie it costs much more to reduce from two to one per cent than it does from three to two per cent.

Estimates for 1990 indicate that the combined oil burning sectors will by then have achieved a 42 per cent reduction in SO_2 emissions from 1980 levels. As a result of business downturn, refinery closures, fuel switching and crude slate changes, emissions are already 30 per cent down. Introduction of residual desulphurisation would be costly and have little impact on overall UK emissions.

CONCLUSIONS

1. Where damage is occurring the treatment of symptoms can produce immediate environment benefits while giving time for effective and economic longer-term measures to be devised.

2. Considerable effort, much in industry, is being made in the UK to abate air pollution and to develop practical abatement techniques. In many cases the technology to reduce emissions is not sufficiently advanced or too costly to be used on a commercial scale.

3. Whether reduction of SO_2 and NO_x emissions will in any event lead to an acceptable solution of the "acid deposition" issue is highly dubious. It is premature and unwise to make costly legislative demands when considerable resources are being expended on the problem and on possible solutions.

1 May 1984

Examination of witnesses

DR A K BARBOUR, Chief Environmental Scientist, RTZ Services, DR G J COPLEY, Group Coordinator, Environmental Pollution, Pilkington Brothers and MR R R MARTINDALE, Deputy Director, Corporate Affairs, Confederation of British Industry, called in and examined.

Chairman

404. Good afternoon, gentlemen, I take it that Mr Edwards is not with us. Is that right?
(Dr *Barbour.*) Yes, I am afraid so, chairman.

405. Who is leading the team?
(Dr *Barbour.*) I think it falls to me.

406. May I welcome you, Dr Barbour, and your colleagues. May I start off by apologising that you should be dragged here so shortly after you have given evidence to the House of Lords Air Pollution Committee. We will try not to burden you overlong.
(Dr *Barbour.*) We welcome the opportunity. I should just give you our apologies for the fact that the Director-General is not here. There is a clash with the CBI Council which also requires the services of Mr Edwards. We did not intend any discourtesy. We have this unfortunate clash with the Council, and those two senior members of the CBI are present. Mr Lemlin, who was coming from the oil industry of Esso, has been called overseas on business. We will try to do our best with the resources available.

407. First of all, may I also thank you for submitting your evidence in writing beforehand which, of course, is extremely helpful to us. I think I can say at once, unless we have time to come to the subject later on, I do not think we need trouble you too much about the scientific cause and effect and the area of disagreement or uncertainty there may be as to what is acid rain, what is its composition, how is it caused and what effects does it have. We are getting a great deal of scientific evidence on those matters, both from United Kingdom scientists and German, Swedish and Norwegian scientists and can form our judgment on that. I would not want to enter into a dispute on matters into which you have not carried out direct research. What concerns us is this: without your making admissions that a problem does exist, that certain pollutants discharged into the atmosphere do ultimately have an adverse effect in some way or another on lakes, on forests and on buildings, let us assume that that is a fact, then from there where do we go insofar as our industry is concerned in terms of cost and in terms of the best means of reducing this pollution, and the effect it will have on our competitiveness as a nation? These are the things upon which you are best qualified to advise us as a Committee. Those are the matters upon which we would like to question you. If you are in agreement with that?
(Dr *Barbour.*) Certainly, Chairman, although I think there will, of course, be an allusion by us to the uncertainty of the link-

[Chairman *Contd.*]

age between emissions and effects. They will be allusions only. For better or worse, we are scientists ourselves so we obviously have views on this, even though we are not actively doing research. Our viewpoint would be that we do need a better understanding of the causes and effects. The effects are several, and may not all be due to the same cause, effects on lakes, effects on forests, effects on buildings and effects on crops. We do think there is a need for much more quantification on that. We are obviously interested in the cost situation, but do recognize there is a problem. It is no use burying our heads in the sand that there is no problem. We need more stress in the linkage between emissions and the problems on the ground. Nobody is denying there is a problem. If there are many effects, there may be a range of solutions to them. We will perhaps get the opportunity to talk about that a little bit. We also do take the view that the UK has been quite active in pollution control. Our emissions have reduced quite considerably for a variety of reasons. The "acid rain problem" has recently increased apparently, so we think that is quite important. As an earnest of our intention here, we have over a few months now had a special Acid Rain Steering Group. I served on the Acid Rain Steering Group. There is a whole range of interests represented, including the CEGB, and so we are fairly up to date with the way things are developing and we are concerned that the abatement technology is not universally applicable. There are a whole range of options we are worried about, particularly those options which generate products, because we are concerned that the products may not be saleable without considerable adverse economic effects. We are also worried about the increase in power costs in the UK. This is a somewhat controversial question. Higher energy users, we feel, are penalised compared with our continental competitors. Those are the main worries we have. I would conclude the introduction by thanking you, Sir, for providing us with a commentary on our paper. We have a list of questions you have put to us. Obviously we would be very glad to answer as best we can questions that you have raised. As I said earlier, we have a rather high scientific bias within the group. We are not international diplomats and some of the questions are a little out of our depth.

408. Thank you very much for the introduction. Could I ask you specifically to elaborate on one of the points you have just mentioned, that is the impact upon our industry on any increase in energy costs?

(Dr *Barbour.*) The impact has to be thought of in two ways. First of all, it is not easy. Going back to basics, we do not know how the directive is going to be applied. This is the first question. There is considerable uncertainty as to which industries the directive will apply to directly, bearing in mind it will probably apply to all industries indirectly through the increase in power costs. As I have said, it is not easy to put an exact figure on the cost which arises. We anticipate it is between five and 10 per cent. Our experience is that industry by and large pays a disproportionate share of the range. We believe industry will be faced with costs arising at the higher end of the range, and intensive users will find that pretty difficult to bear. It sounds quite a small figure—five per cent, but we get many little straws bearing on our backs. Intensive users will find this difficult. The aluminium industry is faced with overseas competition with cheaper labour than ours, with subsidised power, and will find that very tricky. The chlorine industry, tremendous consumers of power, have had to find increased costs for mercury suppression. We are concerned that those extra costs will be very onerous indeed. Dr Copley, you may have some views from the glass industry.

(Dr *Copley.*) I would just like, Chairman, to comment on the NO_2 directive which I have been particularly concerned with, because energy costs come into this quite considerably.

409. I would like to treat as our starting point the costs to this country of implementing the EEC directives.

(Dr *Copley.*) I was going to refer to the NO_2 EEC directives. Nitrogen oxide emissions are associated with high temperature flames, the direct nitrogen oxide emission in the atmosphere. Therefore if industry is required to reduce NO_x formation it involves a reduction of flame temperature. If you attempt to reduce flame temperature you then reduce the thermal efficiency of the process and have to use more energy. That is one instance of increased energy and energy cost. If you reduce flame temperature you also reduce through put and therefore put up the unit costs of your product. Certainly in the glass industry if you reduce flame temperature you will reduce the quality of the product and also make it very difficult to make it.

[Chairman *Contd.*]
So I think there is a direct equation of energy usage and a number of associated questions.

410. You have been speaking of NO_x. What about the sulphur dioxide emissions meeting the EEC directives on this?

(Dr *Barbour.*) There is a big worry about how the directive is going to be applied. I think many of us feel that the most cost effective way of doing this would be to apply desulphurisation to the major power stations and particularly if we are able to persuade our Common Market colleagues that a 60 per cent reduction is unreasonable, unjustified and a 30 per cent reduction is the one to go for in relation to SO_2, then I think the cost will be increased, electricity cost only. But if the fixed limits are taken into account as well and the total industry is faced with a 30 per cent reduction it is extraordinarily difficult to quantify those total costs, and some of those reductions would be an absurdity. As you probably know from the view point of the Alkali Inspectorate, now the Industrial Air Pollution Inspectorate, for the past 15 years or so new sulphuric acid plants have had to be of the Double Contact type. That costs an extra 15 per cent in capital but it reduces its emission by a factor of four in 500 parts per million. If further reductions are required on top of that that is really very difficult to justify, so we would like to know how it is to be implemented.

411. You are talking now of scrubbing gases and Dr Copley was talking of lower temperature burners for NO_x. What about the fluidised bed combustion which tackles both problems, does it not?

(Dr *Barbour.*) This is really an aspect for the power industry basically. I would not be prepared to comment.

(Mr *Martindale.*) I know one company that has been looking at the fluidised bed for its own purposes, but I am sure there is not actually a full scale large unit in operation in this country at all. So we are really bounding on the edge of technological advance in this particular area at this present time. Of course the opportunity to actually install that new technology would only come once in a while and we are really faced with handling the problem of all the existing facilities that we have presently installed.

412. On this general question of rendering ourselves less competitive, if we increase our energy costs, and that seems to be an obvious statement, but how have the Japanese managed? They seem to be or are said to be the biggest competitors that any industrialised country has in the world. They have fewer indiginous fuel resources than we have, yet they are going to introduce very stringent emission controls. Will they remain competitive or will their position be such that we can then do these things ourselves and remain in the position with them?

(Dr *Barbour.*) If I may say so, I think it is rather unwise to make too direct comparisons with the Japanese. Their population distribution situation is quite different from ours. They were faced with some terrible pollution problems 20 years ago and adopted tactics, rightly or wrongly, of extremely onerous regulations, from which they have back-tracked to a certain extent. So I think it is not easy to make a direct comparison between the United Kingdom and Japan. The fact that they are competitive brings into account an awful lot of other factors. My own company licenses a couple of units to Japan and we see the figures from them in comparison with the rest of the world. It has to be admitted that the Japanese are extremely good operators. They are very efficient from all these points of view.

413. What you are really arguing now is, all right, we could take on board these extra costs of eliminating air pollution provided we make ourselves as efficient as the Japanese in other respects.

(Dr *Barbour.*) You are leading me into an area I am not an expert on, but as a scientist I think that is true.

414. Rather sad.

(Dr *Barbour.*) Very sad indeed. The Japanese are more prosperous than we are and can accommodate these costs whether or not they are justified. In our position we have to be more careful as to whether the costs can be borne without pushing us over the precipice.

(Dr *Copley.*) In relation to NO_2 the Japanese have introduced severe restrictions on NO_2 emissions which have little effect of NO_2 concentrations in the environment. They have continued to rise slightly. To illustrate the point that technology must be looked at specifically for each industry, the glass industry in Japan has had to be exempted. Therefore when we start talking about control technologies we will have to look at each industry specifically to see whether the technology is applicable.

[Chairman *Contd.*]

*(*Dr *Barbour.)* In relation to other forms of abatement technology it is fair to say that the Japanese have produced a lot of abatement technology and a certain amount of recycling technology, and that is relevant to the argument of employment in this country. We will have to buy in a lot of technology from Japan and another point of course is that people often say, "If you scrap SO_2 you can make gypsum, you can sell that, what is the problem?" Japan has very little natural gypsum we have large amounts of natural gypsum. We have a serious problem which the Japanese do not have.

Mr Jones

415. Could I establish the ground rules for energy cost? You said that worry was about the range five to 10 per cent and it was at the upper end of that range that it would really bite on industry. First of all, can I ask you what time period you were referring to when you were talking about a five to 10 per cent increase in cost—over what period?

*(*Dr *Barbour.)* If I may say so, you are really asking me to comment on information which the CEGB has provided, which is not fixed. It does vary a little from time to time.

*(*Mr *Martindale.)* There are two points you have raised. One is the question of where in the range the increases might fall with regard to electricity charges, and my understanding through my colleagues, who look after energy pricing, is that the way the tariff structure works the industrial charges for the large industrial users will tend to be higher. They will suffer higher increases as a result of the natural event of building these costs in than the average and higher than the domestic sector, for example. It is the financial tariff structure. Of course, six to 10 per cent, or whatever figure, is based on complying with the EEC directive on a certain understanding on how one might actually do that over the period of the directive. We are talking about somewhere of the order of a ten year period.

416. The evidence we have had so far has established that range as of the order of one to six per cent, rather than five to 10 per cent. That obviously poses significantly different problems for industry?

*(*Mr *Martindale.)* One per cent is a figure which I cannot confess I have ever heard associated with this. One can describe all kinds of scenarios in this area. One per cent has not come across my path.

417. It is a figure which has been given in evidence to us. We have to weigh up which is the most probable. I think the CEGB evidence to us was five to six per cent, rather than six to 10 per cent, which you have been basing your particular assumptions on?

*(*Mr *Martindale.)* We have been working with moving goal-posts!

418. I am trying to establish, on the basis of other evidence presented to us, what effect that is going to have on you. If I could put it fairly baldly, a five or six per cent increase over ten years, as the CEGB has suggested, and there is an upper limit of the range suggested to us....

*(*Dr *Barbour.)* When you say "over ten years", you mean over a ten-year period?

419. Five to six per cent in total over a ten-year period.

*(*Dr *Barbour.)* The bill will be annual. The bill which a customer receives will be five per cent each year over what it was had the event not occurred.

Mr Chapman

420. That is the same with any increase?

*(*Dr *Barbour.)* Of course.

Mr Jones

421. I am trying to establish how much you think that will affect competitiveness?

*(*Dr *Barbour.)* I think that the large users, amongst other factors, will be seriously affected on competitiveness in certain industries. I have cited the larger users of power as industries likely to be affected, industries which are having a pretty difficult struggle to keep going in this country.

422. You could not establish a figure in terms of competitiveness, embracing Exchange Rates and all sorts of other variables, showing for example whether it is likely to be a $\frac{1}{2}$ per cent effect or five per cent overall?

*(*Dr *Barbour.)* It will apply to enough plants which will go out of business. That is what I think will happen. Some plants will not go out of business and others will. In the aluminium industry other plants are keeping going, that will be a serious blow to them. In the chlorine industry there will be a comparable problem.

Chairman

423. I wonder if you could elucidate what you have been saying with a particular

[Chairman *Contd.*]

example? In paragraph 16A of your paper you say that the chemical industry would incur an extra £34 million in terms of their electricity bill if the draft directive was introduced. That is a specific figure. Two questions arise out of that: What is the basis of your figure? How do you arrive at £34 million? Secondly, assuming that the sums are right, how does that affect the competitiveness of this particular industry, the chemical industry?

(Dr *Barbour.*) The figure is based on an estimate that power costs will rise by 7½ per cent. That is the fraction. That, of course, is the power element only. As I said earlier, we are not sure how the directive will be applied. There may be other elements arising from the directive. It is difficult for me to speak for the totality of the chemical industry, but unless everybody in Europe is going to bear those increases we will become less competitive. In commodity chemicals and commodity metals Europe is not necessary a major problem. We have the Middle Eastern people going downstream from oil, and we have got the Far Eastern people and the African countries. We are having a terrible struggle to maintain these basic industries. The chemical industry is a pretty basic industry. I believe we need to keep basic production. I think there will be considerable difficulty at 7½ per cent.

(Mr *Martindale.*) 7½ per cent is applied to the figure which we have for the electricity costs of the chemical industry, which we are pretty confident about. That figure has been established year by year over the last few years and, of course, energy prices are such an important factor to the chemical industry. We have been very concerned about the energy prices for the industry as a whole. It is a very sensitive point. For chlorine manufacturers power costs are 85 per cent of the cost of production. It is very high.

Mr Chapman

424. You mentioned that you were the Chairman of a sub-committee and you were a member of the CBI Acid Rain Steering Group, that the CBI attaches great importance to the problem and how it can potentially affect your members. Surely, you will have discussed this matter with some of your European counterparts, the equivalent of the German CBI. When we were in Germany we were led to believe two things: first of all, that the German electricity industry was going ahead with desulphurising etc. their power stations, well before the EEC directive by 1993, based upon 1980 figures. The reduction they were mentioning to us—and I stand corrected on this point—was the extra cost of electricity in Germany will be at least 15 per cent, and some people thought 20 per cent or even more as a result of this desulphurisation programme. Although I take the point you have just made about the Middle East and other places apart from Europe British industries are competing with, remembering this is an EEC directive which will affect all EEC countries, the problem of competitiveness will not be, perhaps, the problem that you think it could be?

(Dr *Barbour.*) I hope you are right. Going back to where you started, of course, our angle on the Acid Rain Steering Committee is really to study the science of the problem and defend the members' interests. We are, many of us, keen to know what the problem is in some detail. That is a very important aspect of it too. I find it very difficult to maintain a judicial view of the German situation. For example, we were also pilloried recently because of the CEGB approach to the high stack policy. When I visited the Ruhr it was like a hedgehog with 800 foot stacks. The Germans are pretty committed to the high stack policy too, and to coal. It is necessary for them to be in the van on flue gas desulphurisation. There is a feeling amongst German industrialists if the German government is going to be pressurised into an FGD programme the rest of the Community will not be long behind and why should the Germans suffer more than the rest of us? Finally, when I talk to German industrialists in factories they speak in exactly the same way I do. They do not have this wonderful technology that will solve all the problems even with some increase in costs. They wonder why they are needing to do it ahead of time and are trying as hard as possible to get the regulations ameliorated, because they see no justification for them in scientific terms. So I am perplexed about the German situation. I think we have to be very careful that because the Germans are doing certain things therefore everybody else must *ipso facto* do the same things, unless we can establish a really scientific justification for doing it. I think that is a matter of being logical and not being anti-Common Market.

425. Supposing I put these points to you in return. Do we not tend to look at these

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problems as they affect us? Supposing, for example, that 95 per cent of our lakes and rivers lost all their fish and supposing that 50 per cent of our forests were diseased, might not this country, and indeed the CBI is a very important part of it, have a different view to the rather relaxed view that we take, because there is apparently little, if any, effect on our ecological systems?

(Dr *Barbour.*) Through you, Chairman, I would not like to debate those actual percentages, which I suspect might be thought of as being rather high. I am not saying there is no problem at all, but I think we have to be a little bit careful—I visit Germany too—about actual percentages. We certainly do not want to look at it as a national problem; we want to look at it not as an EEC problem, but as a total northern hemisphere problem, including the eastern bloc countries too. We certainly do not want to be bureaucratic in that sense. On the other hand, I do not think we want to be led down the path of taking very rapid action for reasons which are not terribly strongly based. Being in the metallurgical industry I know the town of Sudbury in Canada moderately well. I know dog does not eat dog in this case, but I know the emissions at Sudbury are now being reduced from 2.3 or 2.4 million tons per annum to 1.5 or 1.6 million tons per annum. There are all sorts of reasons why that has not gone more quickly, and I think we have to be very careful of being too precipitous in this situation.

(Dr *Copley.*) May I add a point on abatement, because I do not think we should under-estimate what we have achieved in this country as regards abatement in this country. I have some figures. We have a plant in Germany and there is no evidence that they achieve better emission figures than we do in this country. Remarkably they do not know how they are going to achieve the new figures which have been proposed in Germany. They are writing to us to advise them and their thinking at the moment is that it is going to be so expensive it might be better to pay the fine regularly than to put on the technology which may be available.

426. You mentioned about the particular problem that your glass industry would face if there were requirements and you said that in Japan the glass industry had been exempted because of the particular problem. You mentioned the lower temperature burners in the glass industry. If there were statutory requirements you clearly would campaign for the glass industry for understandable reasons to be exempted, but in the generality of British industry do you think it would just need to be the glass industry or would there be a whole range of other industries which, with your technical experience, you would say in the practicality of things they too would have to be exempted from any national statutory requirements?

(Dr *Copley.*) I believe there would be a large number. I would say that every high temperature, high efficiency furnace would find it difficult, if not impossible, to meet the new NOx regulations for the reasons I have talked about.

427. Could you give some of these industries?

(Dr *Copley.*) I think cement, probably the metal working industry, steel working, certainly glass making, perhaps part of refractories and ceramics industries, that they of high temperature industry.

428. Have they been exempted in Japan to your knowledge?

(Dr *Copley.*) I do not know. Could I just put a piece of paper round the table which illustrates what we have achieved in this country?

Chairman: I think we may be familiar with this because we have had both Department of the Environment scientists and also Warren Spring Laboratories. We are aware of the fact that there has been considerable improvement in the emission problem in this country over the last decade, partly due to reduced industrial activity, and one hopes that will be reversed, and partly because we are using more natural gas. We are aware of that, but nevertheless we did ask this specific point and we were told we still remain uncomfortably near the top, if not at the top, of the emission league in Western Europe, even though we have achieved this reduction.

Mr Jones

429. Could I ask you, supposing we were to join the so-called 30 per cent club, that has one set of implications in terms of costs in controlling emissions. As a second hypothesis, supposing we opted for a substantially higher figure, 50 per cent, shall we say? As a third hypothesis, the 80 to 85 per cent reduction of sulphur dioxide emissions. What comments would you have

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on the particular difficulties as one goes up that range of extra costs for industry? How steeply do the costs rise and at what point do they start getting....

(Dr *Barbour.*) My initial comment would be as a simple scientist that I do not think we should just pluck these figures out of the air, because the differing costs implications are substantial. I think we must have some kind of basis, some kind of scientific or technical basis, for saying, are we aiming at 30 per cent or, as you have said, 80 per cent? I do not think there is yet convincing evidence that any percentage will necessarily eliminate the problems, but clearly a 30 per cent reduction would be a very considerable advance on an 80 per cent reduction, but neither would be justified if it does not cure the problem or substantially ameliorate it. What we have to do is to find out how the problem can be ameliorated and then face up to the problems of meeting that reduction.

430. I am only putting to you a hypothesis. I quite agree about evaluating the scientific effect of the various ranges. I am trying to establish costs at the moment, because that is a vital ingredient.

(Mr *Martindale.*) We have never looked at 85 per cent. If you are looking at total emissions, then the full total does not actually come from industrial sources in the first place, so what you are doing as you pull up the percentages is actually to hit more and more plants. Obviously then you start hitting problems because it is much more cost effective to do the big ones than the little ones, and you will get, as you would expect, rather more little ones to do something about the bottom of the triangle. The question that you face when you are addressing this is whether you can practically fit desulphurisation to those kind of facilities, because it would be impossible on some of the sites. The second question is whether they could afford to do it in any event; and the third question is, would it be cheaper to actually achieve the reduction by a switch of fuel, which would almost inevitably take you away from coal. At what point you get these various stages taking over for each individual company you cannot judge. You know each company will have to have a look at it, on its own, on the merits of its own specific circumstances, which is why we find it so extraordinarily difficult to put a price against the EEC proposal for widening this. I think it is fairly clear that you can evaluate a percentage global reduction for CEGB on the premise that you might tackle the job through a restricted number of plants. We do not know whether the EEC directive is intended to be implemented in the way CEGB want it done. The logic of doing it that way does not actually run very well with actually going to desulphurisation for plants of 50 megawatts.

431. You would be unable to help us with more figures about threshold costs?

(Mr *Martindale.*) It would be impossible.

432. Could I ask, who should bear the cost? Generally I think it is accepted, in this country and in most others, the basic "polluter pays principle". By and large the CEGB pays the cost. Would you have any comments about the other possibilities involving financing, or government part financing? Have you anything to help the Committee in that field?

(Dr *Barbour.*) I do not know that we have. By and large we really think the "polluter pays principle" is wrongly stated. Whoever pays, it is the consumer in the end. Whether there is cause for a Common Market funding in this issue, we have not considered.

(Mr *Martindale.*) Our general attitude is simply that the cost of the pollution abatement should be borne as a normal production cost, and then it is reflected in the price in the proper way. The other part of this is that we believe that is the fairest way of making sure everyone does bear the same burden, because once you get into the area of subsidies it is generally left open for people to judge the level of subsidy they might pay. If we go on to zero we know where we stand.

433. That answer is useful to the Committee.

(Dr *Barbour.*) Can I make a comment on something you said earlier because, of course, it may well be right that our level of industrialisation means we are substantial emitters of SO_2 and NO_x. I would not like it to be thought by anyone that has meant past inaction on our part. We must remember that although we are now considering trans-frontier pollution, local pollution is extremely important for people living in cities. The activities of the Industrial Air Pollution Inspectorate have been important in cleaning up and enforcing our own legislation, which is quite considerable. I can remember cities as they were in the

[Mr Jones *Contd.*]

North and the Midlands and now they are very much better. I lectured for World Health in Katowice not very long ago, someone remarked that Katowice now is like Sheffield was 50 years ago. On the trans-frontier side, with the Eastern Block as well as ourselves, we have done a pretty considerable amount, but that is not to say we have not got to do more. We must remember the local issue as well as the distant one.

Chairman

434. I do not want you to feel that we have not recognised the value of our clean air policy in this country. Since the 1950s it has got rid of most of the carbon dioxide and left the sulphur dioxides that have to be dealt with in other ways. Also the tall stack policy has removed a lot of our local pollution and, therefore, we are now getting complaints from overseas that we have merely shifted the stuff somewhere else.

*(*Dr *Barbour.)* The Germans have a strong tall stack policy.

435. I wonder if I could take your minds on to another aspect of the problem, that is, reducing fuel and energy costs by energy conservation. There is passing reference to it in one sentence in which you say: "More energy conservation—a developing trend in the UK industrial sector which will continue and which will, in the longer term, contribute significantly to the reduction of emissions." That is all that you say. I would like to know a little bit more about it. We had evidence from the Friends of the Earth who have indicated to us that probably the best solution to this problem is that of energy conservation. One particular example they gave us was the manufacture of refrigerators. They say that the policy is to possibly economise on the cost of making refrigerators so that they are not as well insulated as they could be made, and the consequence is that they require more energy to work than they otherwise would if better insulated. The saving is on capital cost in order to sell in the marketplace, whereas the purchaser is unaware that he or she is buying a product that costs something more to run, than if they paid a little bit more money. This, I would have thought, is essentially CBI territory—the advice and recommendations you make to your members. First of all, is that evidence that we have received, and I have indicated to you, valid? If it is valid, could there be any kind of rethinking amongst those manufacturers who deal with that particular commodity? Are there other areas in industrial manufacture where greater attention to producing appliances that use less energy would help this overall problem?

*(*Dr *Copley.)* Energy costs are such a high proportion of the high temperature industries in particular, and a great deal of work has already been done on energy conservation around the manufacturing plants through insulation and operating practices, so you very quickly now are getting into the law of diminishing returns. You can keep improving a little bit. It means you are going to achieve improvement, in terms of emissions from the stack, by using slightly less fuel because you are more efficient, of the order of the odd per cent but nowhere near the 60 to 40 per cent which is being proposed. I think we are coming into the law of diminishing returns. This has been a frantic area of work since the mid-1970s. We found our German plant was rather more energy efficient than the UK plant. We have been learning some lessons from them.

436. That is the manufacturing process? Conservation in the manufacturing process?

*(*Dr *Copley.)* Yes.

437. I was directing my question to the case that goods were being sold to the public at reduced costs but more wasteful energy?

*(*Dr *Copley.)* My thoughts go back to the basic materials, steel or glass or plastics, or whatever.

438. Is there room for improvement in those fields?

*(*Mr *Martindale.)* Firstly, on the general question of industrial use of energy within its own premise, last year we held a conference on combined heat and power and it was an absolute sell out. The interest is absolutely inordinate to keep the energy bill down. I am surprised 'fridges were particularly cited by Friends of the Earth. I was not present when they were here. Cookers are another area and I think that the incentive already exists. It is not an area we, ourselves, get involved in very much. If one looks at the consumer reports, Which Reports, you will find that the focus has gone on to the cost of operating both cookers and refrigerators and so on as part and parcel of a normal cycle. That is really a reflection of the price of people's domestic bills, so there is already an emphasis there. Manufacturers obviously have to choose

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their own balance between the cost of manufacture and their selling price. It is a balance question. It is not one we generally get involved in.

Mr Chapman

439. I do not want to put words into your mouths, but, as I understand it, what you are really saying is that there is no conclusive proof or sufficient evidence to justify the Government embarking on a course which would cost hundreds of millions of pounds and may not succeed in solving the problem of the particular pollution that we are concerned about. Of course you would be very pleased if suddenly some research established there was no connection between SO_2 and NO_x emissions and the problems being caused. I would not like to speak for them, but this was the gist of what the Friends of the Earth were saying in their evidence, that it would be wise to embark on implementing the EEC directive, because if of course subsequent research proved that there was a link, then obviously we have taken the right decision, but if it was not it would not actually cost all that much in the early years of implementing the EEC directive. Would you object particularly to that strategy or would you say that if we embark upon implementing the EEC directive that all this would involve industry in a great deal of money even from year one?

*(*Dr *Barbour.)* I think, through you, Chairman, there are serious problems here, because I think there is a widely held view that something has to be done about the degradation of forests and Scandinavian lakes and perhaps the Scottish lakes as well. People say that if there is anything going in the stack it is going to cause damage somewhere. It is a bit like the lead in petrol. It becomes an unsaleable proposition. Toxic substances coming out of a tail-pipe must inevitably do some harm. The problems are not all that bad, so let's do it. Maybe that politically is a wise thing to do. We would just caution perhaps that where does it end, when is the next issue, and so on? I remember well the chlorofluorocarbon question and I have some close knowledge of this subject. In 1974 they were predicting there would be a five per cent depletion of stratospheric ozone and more and more research was done and by 1980 the depletion was predicted to be 16 per cent. Now that more research has been done it is down to five per cent. No-one is saying that the acid rain problem is as relatively insignificant as the CFC question. The CFC question can be settled with much less social damage than the damage to industry for a wrong decision here. I think we have to be a bit careful here, and I think to adopt strategies which are not justified is not a good policy. We have done a great deal in this country, often not publicised, and I do not think we should be rushed into doing this where the technology is not proven and the cost will be high. When there is strong evidence we will then have to decide whether it is 30, 50 or 80. We do not even know that, and that is a tremendous difference in costs. We should not underestimate what this country has done and our view is still that in these very, very important issues the expertise of the Alkali Inspectorate, now the Industrial Air Pollution Inspectorate, should be in the fore in DOE councils in this matter. We believe that the inspectorate should transfer back to the DOE. These are very, very important questions and I think there is some loss of focus in the Industrial Air Pollution Inspectorate being operated second-hand from the DOE, as it now is. My judgment would be that there is much more linkage between air pollution and other forms of environmental pollution than there is between external air pollution and the conditions inside factories. So I believe we should have the Air Pollution Inspectorate back at the DOE. It is easy enough to say, well, what is 30 per cent and it will keep the Friends of the Earth quiet, but I really do think we must have a reasonably well established linkage between the cost and the effect, and my reading of the situation is that the linkage is getting more and more blurred, even in recent months, than it was a year or so ago. I do not think we should rush down this track merely because of the rather strident publicity which we are subjected to.

*(*Dr *Copley.)* I think the statement which Mr Chapman made is not quite as clear-cut as it appears, because if we were in the position of being forced now to control emissions from industry whether or not that was the right thing to do, then research and development would be necessary in each industry to develop the ways they were going to achieve that control and to develop measures which may at the end of the day not be the right measures. It is not as clear-cut as, let's put control on furnaces.

*(*Mr *Martindale.)* Perhaps if I may add two points, one might question why all the hurry, because the relationship between SO_2 and nitrogen oxides and damage to trees, as you will know, has been put on one side

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to a large extent in recent times. Even if there is shown to be a strong connection between emissions and lakes you will not actually remove the problem at the far end by simply putting emission control on at the other end.

440. By that do you mean that in some of these affected lakes the process has gone too far for any hope of regeneration of fish?

(Mr *Martindale.)* I think you will have to treat the lakes in any event, irrespective of whether you put emission control on or not. You will not get a natural event which happens very quickly in actually removing the acidification in lakes that is already there. You will have to take some countermeasure to treat the symptoms as well as do something about the cause. So one is bound to do something of that sort. Therefore if you are going to have to do that anyhow, then that would seem to provide adequate reason to do the treatment and to carry on the further research work to try and establish what on earth is happening. I do not believe there is a genuine time-scale pressure in that area. The last comment I wish to make, if I may say so slightly tongue in cheek, is that one would expect the Friends of the Earth to say something of the sort that we know they said—you know, pay out the money whatever—because they are not actually paying the bill. We are concerned because we can see the size of the bill that is involved and it has to be paid for, somewhere along the line, as a result of the efforts of our members.

Chairman

441. Thank you very much, gentlemen, for coming to see us this afternoon. I can well understand the caution with which you admonish us in view of the enormous sums of money that are involved in taking remedial action and the impact this would have upon the competitiveness of our industry. Having said that, there are a number of points in your paper that I would like to briefly draw to your attention. We have not questioned you on these because we were conscious of the clock and I did not want to detain you in what might evolve itself into an argument between us. May I say, we have received contrary evidence to the way in which you put the lack of nexus between emissions and fish kill in rivers and lakes. The thing is a little bit more positive than you would lead us to believe in your paper. I think we accept much depends upon the geological situation of the lakes in question, whether it is on granite or calcium, but nevertheless the absence of calcium does mean lakes are more sensitive if there are emissions and acid rain and consequently fish kill. One is left with the problem of, what should one do? Mr Martindale has suggested liming. It is impossible in Norway with fast running waters. It is not a solution there. In a situation where it is a palliative measure and heavy metals are deposited, the moment you stop liming you get pollution from the metals. We have received a lot of evidence of that kind. Does one continue both improving the atmosphere and liming? That is the other question. I think I should draw that evidence which we have received from other sources to your attention so perhaps you can follow them up. They may have some effect on your own thoughts. In so far as buildings are concerned, we have received evidence that there is a direct link between sulphur emissions and the effects on buildings, as you will find on your next visit to Koln Cathedral. In so far as health is concerned, respiratory illnesses on children, copper poisoning due to erosion of copper pipes and lead poisoning because of erosion of water pipes, you just brush aside, saying there is no evidence of effects on health. There is a certain amount of evidence on effects on health which we will have to evaluate in the course of our Inquiry. As you are so positive on those matters in your paper I thought I might draw your attention to it. I hope you will forgive me for doing so.

(Dr *Barbour.)* Thank you for raising these points. I was going to make the point that there are some things in the questionnaire and you have raised some others, which we might perhaps respond to in writing. That might be the best way of dealing with the question.

Chairman: Thank you very much, indeed.

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MONDAY 25 JUNE 1984

Members present:

Sir Hugh Rossi, Chairman

Mr Richard Alexander	Mr Robert B Jones
Mr David Alton	Mr Chris Smith
Mr Sydney Chapman	Mr John Mark Taylor

Memoranda submitted by the Forestry Commission

ACID RAIN

In your letter of 19 March you asked the Forestry Commission to provide the Environment Committee with evidence about the effect of acid rain, including dry depositions, on forestry in this country. You subsequently wrote to Dr W. O. Binns and Mr R Lines of our Research and Development Division, seeking evidence on work they had undertaken in this field; you indicated that it would be acceptable if this were included in the Commission's general evidence, and this is what we have done.

2. The area of concern to forestry is limited effectively to the second of your terms of reference—to examine the environmental effects of acid rain. It is clear, however, that the matter of deposition of pollutants is relevant to these effects. I attach (Annex A),* as a main part of my evidence, a copy of a Forestry Commission Research and Development Paper recently prepared by Dr Binns. This will be available in published form in late May when printed copies can be sent to the Committee if desired.

3. The principal conclusion from research undertaken on the interactions between trees and acid depositions in Britain is that, under natural conditions and apart from forests close to intense sources of pollution, no damage to forests has been observed. While this is true today, it is not certain that damage may not have occurred or that it will not occur. Trees grow slowly, of the order of only a few per cent of their current size in each year, and even a substantial proportional reduction in annual growth such as 20 per cent is difficult to detect. The concern that foresters have is that, in soils derived from acid rock, there may be effects working through the higher than normal loadings of acidic inputs. This could, if continued unabated or even if continued at lower levels, have deleterious long-term effects on root growth and nutrient uptake, leading to reduced growth and tree stability.

4. To date, the effects of acid depositions on forests, so far as they have been assessed, have shown themselves at one remove from the trees themselves, namely in the water moving out of the forest soil directly, or indirectly through plough furrows or forest drains, to streams flowing through the forest. In certain cases, such as Loch Enoch in Galloway, acidity has increased and fish stocks have disappeared in the absence of trees on the water catchment. In other places, notably on acid rocks, the presence of forests has apparently accelerated the increase in acidity of streams and the fall in fish stocks. To establish whether forests are the sole or principal cause of this loss of fish and to determine the processes and pathways involved, research was initiated several years ago in a number of Forestry Commission forests in west Scotland, and more recently in forests in south Scotland and mid Wales. It is increasingly clear that in many streams carrying brown

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* Forestry Commission Research and Development Paper No 134, Evidence not printed.

The cost of printing and publishing these Minutes of Evidence is estimated by Her Majesty's Stationery Office at £1,500.

trout in areas of acid geology, a small increase in acidity renders it impossible for fish eggs to hatch and the fry to survive, and the concern expressed by angling interests is concentrated in such areas.

5. The Forestry Commission maintains close collaboration in research on these topics with the relevant bodies, notably the Freshwater Fisheries Laboratory of the Department of Agriculture and Fisheries for Scotland and the Freshwater Biological Association of the Natural Environment Research Council. The Commission provides sites for work; participates in the joint design of the experiments (which are, however, carried out by the relevant institute or laboratory with expertise in water and fisheries matters); and carries out operations called for as part of the experiment. The treatment sometimes calls for the removal of the trees, and there may then be partial felling confined to a band on either side of the streams under investigation or felling over larger areas. Sometimes the liming of lochs is also undertaken as part of certain experiments.

6. The Forestry Commission is carrying out experiments of its own concerning soil water quality, with the Institute of Terrestrial Ecology undertaking the requisite chemical analyses, and collaborates in joint experiments with the Institute. While these studies were not established directly to provide evidence on effects of acid depositions, they are capable of indicating certain of the chemical and biological processes at work in acid soils where the influences of man-made additions to acidic inputs are of concern. In addition, the Macaulay Institute for Soil Research at Aberdeen carries out commissioned research on tree growth and soil interactions for the Forestry Commission. In recent years this work has included investigations on a number of sites in Scotland of the effects on soil water of factors such as tree age.

7. The Forestry Commission maintains close contacts with forest researchers overseas, notably in West Germany and Scandinavia. Such liaison is essential to the growth of understanding of the different processes at work, as well as in the work of such bodies as the ECE Committee on Transboundary Pollution.

8. The Committee will also be aware of the EC Commission's proposal for a Regulation establishing a Community scheme to provide forests in the Community with increased protection against fire and acid rain on which an Explanatory Memorandum (No 8125/83) was sent to Parliament on 22 August 1983. A copy of the Explanatory Memorandum is attached (Annex B) for ease of reference. It will be seen that this single proposal seeks to cover both forest fires and atmospheric pollution and is far from clear in its implications. Forestry Commission officials have been attempting to clarify the EC Commission's intentions under the proposed Regulation in Council working group meetings in Brussels where discussion is proceeding slowly, particularly since further consideration needs to be given to the legal basis proposed for such a Regulation. On 26 October 1983 the House of Commons Select Committee on European Legislation classified the proposal as being politically important but not for debate.

G D Holmes CB,
The Director General
13 April 1984

Annex B
8125/83

EXPLANATORY MEMORANDUM ON EUROPEAN COMMUNITY DOCUMENT

Document 8125/83 of 4 July 1983 concerning a proposal for a Council Regulation establishing a Community scheme to provide forests in the Community with increased protection against fire and acid rain.

Submitted by the Forestry Commission, 22 August 1983.

SUBJECT MATTER

1. A Community scheme is proposed under which Member States would submit annual programmes for the protection of forests against fire and acid depositions to the European Commission who would then decide on reimbursement. The Community scheme would last for 5 years from 1 January 1984 with an estimated funding requirement of 100 million ECU (75 million ECU for fires and 25 million ECU for acid rain). The proposal is based on articles 43 and 235 of the Treaty.

Protection of forests against fires

2. The Commission points out that forest fires entail losses and heavy expenditure both for the Member States concerned and the Community. They affect the productivity of forests, increase the trade deficit and have a harmful effect on the environment, neighbouring agriculture and tourism.

3. The Community would make financial contributions of up to 30 per cent of the cost of implementing stricter fire protection and fire fighting measures, including the purchase of materials and equipment, of up to 50 per cent of the cost of training, harmonisation of methods, standardisation of equipment and research, and of up to 100 per cent of the cost of transporting equipment and personnel in the case of mutual fire fighting assistance between Member States. The Community would also bear up to 100 per cent of the cost of co-ordinating these activities. This would be undertaken by the EC Commission with the assistance of an Advisory Committee consisting of 2 representatives from each Member State.

Acid Rain

4. The Commission states that acid depositions are known to contribute to the deterioration and death of forests but that this damage has not yet been quantified. It proposes a Community scheme involving a financial reimbursement of up to 50 per cent for the establishment of a network of monitoring posts in the main forest areas of the Community, and 50 per cent for the setting up in each Member State of a multi-disciplinary team of scientists to draw up periodic forest health reports and to propose action. The co-ordination of the work of these teams would be financed by the Community, and would be undertaken by the EC Commission with the assistance of a Scientific Committee. The Community would also bear up to 100 per cent of the cost of experimental pilot projects to ascertain preventive and curative methods.

MINISTERIAL RESPONSIBILITY

5. The Secretaries of State for Scotland, Northern Ireland and Wales and the Minister of Agriculture, Fisheries and Food have responsibility as Forestry Ministers. The Secretary of State for the Environment and the Home Secretary also have an interest.

IMPACT ON UK LAW

6. The Regulation would be immediately binding on all Member States. Its effects are financial and there would be no impact on UK law.

POLICY IMPLICATIONS

7. Fire protection is an essential part of forestry but the need for additional measures and for Community financing and co-ordination requires careful consideration. The extent of monitoring of acid rain depositions in forests and the need for Community financing and co-ordination in that field are similarly matters for detailed consideration.

TIMETABLE

8. The Commission has transmitted the document to the European Parliament and the Economic and Social Committee, and has suggested that the Council should act upon the draft Regulation by the end of 1983.

Gray of Contin

Examination of witnesses

MR A J GRAYSON, Director, Research and Development, DR W O BINNS, Research and Development Division, and MR W F SHERIDAN, Secretariat Division, of the Forestry Commission, called in and examined.

Chairman

442. Good afternoon, Mr Grayson. I thank you and your colleagues for coming to us this afternoon and also for the papers that you have already submitted to us which we have read with great interest and found extremely helpful. We would like to ask you a few questions about your papers in a moment, but before we do that, I wonder if you would care to introduce yourself and your colleagues?

(Mr *Grayson.*) I am Director of Research. Our research covers many aspects of forestry. There has been a very heavy emphasis in the past on wood production and now with a growing emphasis and recognition of environmental issues both in the field of conservation and some of those forest influences which are latterly coming very much to the fore. Particularly notable examples I can pick out are water quantity and water quality, which I think we may be discussing with the Committee this afternoon. Our remit runs over the whole country and we work very closely with certain sister institutions in the research field, notably with the Natural Environment Research Council, and particularly on environmental matters. Dr Binns is Head of the Site Studies Branch and has taken a special interest in this field over the last seven or eight years and he has produced two publications, one of which we have put in evidence before your Committee. Mr Sheridan is in our Secretariat Division in headquarters and is responsible for Community affairs and he is concerned especially at the moment with matters close to the Committee's business, namely a draft Regulation dealing with fires and acid rain.

443. You make reference in your paper first of all to work that is taking place in other European countries and then also you deal in your paper with the situation here. We are, of course, most interested in what you have to say concerning the knowledge you have acquired regarding the perils there may or may not exist within the British Isles but before we go to that, could I ask you one or two questions about your contacts with scientists overseas? One of the matters that seem to be emerging from the evidence we have received so far is that sulphur emissions may have some connection with the acidity of lakes, streams and fish loss, possibly not the damage as was originally thought in so far as damage to trees is concerned, and the Germans are looking elsewhere for the culprit, as it were. Now on pages 10 and 11 of the printed version of the paper in front of us you do not make any mention of ozone at all, and I would ask you to say something about that and also to say whether there is any monitoring of ozone taking place in this country?

(Dr *Binns.*) I think, Chairman, we do mention ozone. It is at the top of page 14 of the printed version, the very first line. So we have mentioned it there. We ourselves, of course, are not doing any monitoring of ozone because that is the responsibility of other bodies in Britain.

444. Do you know whether any research is taking place into ozone in this country, from your own knowledge?

(Dr *Binns.*) Oh yes. The universities, in particular Lancaster, have been working on sulphur and nitrogen compounds and are now taking a greater interest in ozone. Imperial College in particular is working under Dr Nigel Bell on a project which is looking at the effects of ozone and other pollutants on different species of forest trees, and the Central Electricity Research Laboratories are just mounting a field trial, again looking at combinations of sulphur dioxide and ozone, on Norway spruce.

445. In so far as damage to trees in this country is concerned, I understand that in 1983 in Sweden local forestry management officers were brought together and they were briefed on the characteristics of acid rain or ozone damage and were asked to examined their areas. Up to that point in time they were not really, or did not seem to be, aware of much damage, but after they had been asked to carry out this particular exercise they did find much to their alarm that there was extensive damage to trees in Southern Sweden. Are we doing anything similar here?

(Mr *Grayson.*) Could I just say about their surveys that I think there are always difficulties about initiating something when

[Chairman *Contd.*]

you are not quite sure what it is you are looking for. We have become so well seized that point, I think, just by reference to the Swedish example, where they are fairly keen foresters and good at observing their trees, that we have become more watchful. I am slightly disturbed at reports in the Press about someone who has been going round and has found out all sorts of things which we have ascribed to rather different factors or forces, and I would suggest we are trying to do this as honestly and objectively as we can. I wonder if it is true to say that it has really been proved in Scandinavia that this damage they say they have seen is really attributable to those influences. It is moderately extensive on individuals, they have found, but only on a very small number of trees in the southern counties of Sweden.

446. Have your officials or any of you been to Sweden or to the Black Forest?

*(*Mr *Grayson.)* Can I speak for myself in respect of the Swedish situation? I was there last year when these sorts of things were being discussed. It was before that survey was conducted, and many of the Swedish foresters were doubtful whether the effects were any different from those they had known about for decades past. Could I ask Dr Binns to answer for Germany, because he has visited that country in successive years recently.

*(*Dr *Binns.)* First of all last week I was talking to Professor Folke Andersson from Sweden about the damage and I had also been in correspondence with him before that, when we got the first reports, and he considers the damage has arisen in the last year or so, and is not long-standing but unnoticed. The fact that they had had the driest summer for about a hundred years he is sure contributed to the extent of the damage. I was in the Black Forest last week for the second time in about eighteen months and I am in regular contact with researchers at Munich and Freiburg in particular, in connection with the forest damage surveys and the development of research, and I have also been to Bavaria and to Lower Saxony to look at the forest damage.

447. In Germany they saw signs in the 1970s, did they not, but they did not really become terribly alarmed until the last two or three years?

*(*Dr *Binns.)* The signs they saw in the 1970s were of damage to the European silver fir and because that species had suffered a period of damage in the past, in the last century, in the 1880s and the early 1920s, it was thought this was the same syndrome. It had never been explained incidentally. But when it got very bad they became alarmed because it appeared to be much worse than previously recorded. The damage to Norway spruce did not appear until the early 1980s.

Mr Jones

448. You alluded to the latest reports that you felt were somewhat alarmist. I take it you are referring to the reports in mid-June in the *Guardian* and the Friends of the Earth Scotland Survey?

*(*Mr *Grayson.)* Indeed.

449. Could I ask if you have been supplied with a copy of the results of that survey?

*(*Mr *Grayson.)* Only in the last quarter of an hour, regrettably, I am afraid.

450. That goes into considerable detail over a wide range of subjects up and down the country and it makes specific allegations about both the causes and the effects. Will you be, as it were, checking that survey to see whether you can confirm or refute it?

*(*Mr *Grayson.)* Yes. I am glad you have given me this opportunity of saying what we are doing about it. One of the places where really rather heavy emphasis was placed on supposed damage by acid rain was at Whinlatter Pass on the northern part of the Lakes outside Keswick. Our Senior Pathologist at our northern research station at Edinburgh is with a colleague, looking through a lot of records to do with climatic events in the last six months or so, because they have other suspicions about the cause of damage, and we shall be looking at other places where we think it is worth doing so. I understand the Committee is travelling both north of the border and into Cumbria and we hope very much we will be able to talk about those matters on site with you, both with regard to aspects that may come up on the water side as well as directly on forest damage. If possible we will talk about that on site—Whinlatter No 35 appears in these examples—and Dr Binns will be there to talk about it as well as our pathologists.

Chairman: That will be next week, yes.

Mr Jones

451. One of the results put to us is that the damage to trees is not attributable solely to one bad cause, which I am sure is reasonable, but is the sum total of all sorts of different stresses, one of which you have made reference to—drought—in connection with Southern Sweden, but others might be frost or wind damage or whatever. Would you agree that one of the principal causes of the damage was likely to be pollution of the nitrogen oxide and ozone related type.

*(*Mr *Grayson.)* I am afraid I cannot really answer that question affirmatively because it depends what you mean by damage and I cannot say the damage is caused by anything until we have actually determined it. In the cases we come across of damage we always look for pathogens of a commoner kind, and very often it has been proved that they were fungi or something like that which were living on the particular trees. You may get a concatenation of damaging influences which together might do awful things, but I do not think we have found it necessary to invoke the acid deposition hypothesis except in a few places near point sources where you have a big chimney stack or there are steelworks or something like that. It is fair to say that SO_2 is something we have looked at off and on in the South Wales coalfields where we have gone back recently, being concerned about what was happening there. That was one of the places where there was a combination of factors, which could include some forms of acid deposition. But we are not finding examples where we find it necessary to invoke this hypothesis because we do not have the same combination of symptoms as we have heard about from German colleagues.

452. Could I ask Dr Binns a question on one of the technical aspects of the section of his paper on the effects of pollutants on soils? He refers to the amount of calcium in a 1 mm thickness of granite being able to neutralise 200 years' worth of acid rain at a given pH. Is that not based on the assumption that the calcium bonding is equally strong in igneous rocks as in limestone? Is that a meaningful statistic to quote, because the areas we have looked at where perhaps there is a counter effect to the acid rain of neutralisation have largely been limestone and other sedimentary rocks and there is lesser bonding?

*(*Dr *Binns.)* I think that is quite right. It begs not only the question I put, but other questions as well. It is merely a calculation of the amount of calcium present and these rocks are not in fact deficient in calcium. It is the possibility of getting it mobilised and therefore doing its job of neutralising natural or man-made acidity.

453. That does not come out in the paper very well.

*(*Dr *Binns.)* I am sorry it does not, I had hoped it was clear that it was unlikely that you would get rapid mobilisation of such calcium from the points I make in the rest of that sentence.

Mr Smith

454. I wonder if I could possibly just take you back to the damage to Swedish forests, which you seem to pass rather lightly over. You said two things which I found puzzling. The first was that Swedish foresters who you were talking to had said that they did not think that this was something that had been going on for a long time that they had not noticed; they thought it was very sudden. That does conflict with what some of them said to us when we were there when they were doubtful about whether it had been happening before they began to notice it last year or not. The other thing that you said was that the dry year in 1983, I think you said, had contributed to the damage. That may have been the case, but in your discussions with them what else in their opinion and yours has also contributed to the damage, because you did not tell us that?

*(*Dr *Binns.)* There were two dry years in fact. Both 1982 and 1983 were dry. There had been a previous occurrence of unexplained sub-top dying in Norway spruce in—I forget exactly when, but perhaps ten years before, which has never been satisfactorily explained and went away on its own. I can only repeat what Professor Andeusson told me last week, that he thought it was a new event; it had not been there five years before. He was very cautious about attributing causes because he said we do not have the evidence, but they do know that a certain amount of pollution comes north when the winds are in the south, from East Germany and Poland I should imagine, to southern Sweden. They think there is a pollutant component but they are not prepared to put their money on the table as yet because they have not got the evidence.

Mr Chapman

455. I wonder if I could ask Mr Grayson about the letter of the Director General of the Forestry Commission, Mr George Holmes and the foreword from yourself. The evidence is written by Dr Binns and indeed he is the author of the publication 134 which accompanies the evidence. I do not wish this question in any way to sound offensive, but since the evidence and acknowledgements finishes off, "The author however remains responsible for the views expressed", is this in fact the evidence of the Forestry Commission or is it that of Dr Binns, albeit a most distinguished member of the Forestry Commission?

(Mr *Grayson.*) No, it is the evidence of the Forestry Commission.

456. One of the things we are finding is that experts and professionals do disagree on this issue. Can we take it this is the collective and unanimous opinion of the Forestry Commission?

(Mr *Grayson.*) I do not think we can say unanimous, but collective, yes.

457. Paragraph 6 of the Director General's letter to us refers to the experiments and studies that have been carried out not only by the Forestry Commission but also the Institute of Terrestrial Ecology and the Macaulay Institute for Soil Research at Aberdeen. Could you give us any indications when these studies will be completed?

(Mr *Grayson.*) These are studies which have been going on for some while and some of them are of their nature very long-term because one has to observe a site for a while under some treatment, change the treatment and then see what the outcome is. So I suppose in the case of one of the major sites, Beddgelert in north Wales, we will wait for another two years or so to get really full evidence of what are the changes in, for example, soil solutions, composition from land where the trees have been taken off compared with the land before when it is under forest and therefore might have been collecting some form of acid deposition. Much also has been done and reported by Professor Miller.

458. Can I press you on the Forestry Commission studies? You mentioned two years before there would be a reasonable indication. Can you be more precise than the period of two years? Would you not be able to form pretty conclusive opinions before two years is up by making sensible judgments? I ask that question in the context of this being an extremely urgent matter, at least in the eyes of the Germans and the Swedes and the Norwegians.

(Dr *Binns.*) It is a bit difficult to answer that exactly because, as is implied in the submission, the analyses have been done by another organisation and it would be impertinent of me to say when they expect to publish their results. Our colleagues all doing the analysis are in the Institute of Terrestrial Ecology and have been involved in the experimentation all on these sites.

Mr Alton

459. There is a fairly aggressive letter in the Guardian this morning which suggests that maybe complacency is not called for. Anyone reading your conclusions, particularly the first sentence, "There appears to be no threat to British forests of damage similar to that seen in Central Europe", would assume that everything is alright in this country. There are suggestions that places like Wyre Forest are beginning to suffer from the effects of acid deposition. I wonder if you would care to comment on that. Might I also ask you: when we were in Sweden one of the things which struck me and I think my colleagues on the Committee was that some of the problems in Sweden and perhaps parts of Central Europe as well were caused by over-aggressive forestry policy. It may be there are too many trees being planted and felled and replanted and naturally the forests are running out of life. Is there any substance in that hypothesis?

(Mr *Grayson.*) On the first one on complacency, we have already indicated that we do keep very close contact almost on a man to man basis and not only through working groups of international organisations, which is another means of keeping contact with people, so as to be aware of exactly what they mean by this sort of damage which has been viewed by various people in Germany and now has been surveyed fairly systematically in 1982 and 1983. It is not something that we are finding evidence of in this country, having taken into account the combination of symptoms these German foresters have identified. Of course while there are rather large numbers used to express the hectarage over which some damage has been observed, the actual damage is very small. We recently met some German foresters from Munich who are

[Mr Alton *Contd.*]

doing some experiments on trees in growth chambers. They said the cut of timber has probably not been altered but its location may be; where some trees have died they have taken them out, in place of healthy trees in the same forest. I would like to indicate that the actual effect of this does tend to get exaggerated. On the question of actual method of management of forests, it is, I think, of some interest that both that rather indicative survey to which you, Chairman, referred from Sweden, as well as the evidence in some of the German surveys—though not all of them—tend to indicate that there is more damage in the older classes of tree over three-quarters of the way through the rotation than in younger trees. It happens that Germany has long had a policy which tends to be rather gentle, I suppose you might say, in the way it exploits the forest and tends to use native trees as opposed to exotics and long rotations rather than the short rotations that you would find in Britain.

460. Can I question you further on the Wyre Forest? In the correspondence columns some well qualified people have been talking about the tinselling effect we saw in Germany, which they say they have seen in our country. They cite particularly the Wyre Forest example.

*(*Mr *Grayson.)* If I may, I would prefer that we answer that as soon as we have got the pathologist's report, and I will let the Committee know that. I do not think I can answer because I have not seen it.

Chairman

461. Mr Grayson, a moment ago I understood you to suggest that the damage to trees was mostly amongst the older trees and there was little evidence of damage amongst saplings. Is that right?

*(*Mr *Grayson.)* May I qualify that by saying it is rather more apparent in the older age classes than the younger. It is not absent in the younger but there is more in the older classes.

462. Because some of the evidence we had in the Black Forest was that the damage had occurred certainly to the older trees with the high canopies exposed to sunlight and when those were removed and spaces opened and the saplings then lower down became exposed they began to suffer. Did you find any of that in your visists, Dr Binns?

*(*Dr *Binns.)* Yes, Chairman, I think this is probably true. It does seem that it is the exposure to the light that is all important to really small trees, I mean trees two or three metres tall. The damage has been when they have been out in full sunlight and not when they have been in the canopy of older trees.

463. Does that not seem to argue towards ozone as a possible explanation to the damage which is being suffered?

*(*Dr *Binns.)* It does indeed. That is one of the bits of circumstantial evidence which suggests that ozone rather than SO_2 is one of the primary causes.

464. That is why I was a little surprised at an earlier answer when I was told that you, the forestry people, are not carrying out any monitoring in the ozone at higher altitudes. I would have thought that this was a likely cause of damage to trees and you would have wanted to check the damage of ozone.

*(*Dr *Binns.)* I hope we shall not be accused again of complacency, but I think we have all to see ozone damage at high altitude, which is similar or different from the damage we have seen in the past, which we can attribute to exposure to sunlight, before we go to the expense of monitoring at high altitudes. We know that the number of stations measuring ozone is being extended by Warren Spring and the Institute of Terrestrial Ecology and we will lean on their expertise and encourage them to put them in other places than they are at the moment.

465. Would what you have seen in Germany that we have just been discussing not lead you to feel concerned that perhaps we ought to be looking a little more closely than perhaps we have been doing up to now as to the possible effects of ozone on our trees?

*(*Dr *Binns.)* I think what we have to look for is damage to forests, not assuming ozone or anything else is the cause. What we need to find is instances of trees and forests which are suffering from some form of damage which is not explained by the normal agents with which we are so familiar. I would like also to say here that if we can say we have had unseasonal frosts, dry winds and the trees go brown—this happens from time to time—and if the meteorological records show that we have had similar sorts of occurrences in the previous six months and we have experienced similar

[Chairman *Contd.*]

damage, we would accept that explanation rather than saying it must be air pollution or acid rain. The same applies to fungi and insects.

466. Really, what you are saying is you want to wait for evidence of damage to the forests before you start troubling yourselves whether we are experiencing similar atmospheric and climatic conditions that exist in other places in Europe where damage has been suffered or experienced, is that what you are saying?

*(*Dr *Binns.)* Not quite. What I am saying is the business of measuring these pollutants is being done by people who are skilled in it and it is an area in which we have no experience at all. It would be foolish for us to move into this field. The second point—we want to wait until we have got serious damage before we do anything—no. We are going to start looking at carefully selected places to see whether we can find any case to answer such as has been written about recently by the Friends of the Earth on causes of damage with which we are only too familiar, if we have anything new—because as has been said already we are familiar with damage from local point sources and the South Pennines is known as an area difficult to grow trees, we know in the vicinity of Port Talbot steel works there has been extensive tree damage, these we are all familiar with—what we have not seen is a new phenomenon which the Germans call the new forest decline. This is a new phenomenon, we have not seen anything of this kind yet in Britain, although all our pathologists have been looking to see this.

467. You have been looking out for it?

*(*Dr *Binns.)* Yes, of course.

Mr Taylor

468. I wanted to ask first of all, our witnesses if they could just remind me of something that I am sure has already been said or is in their literature, for what proportion of Britain's forests are you custodian?

*(*Mr *Grayson.)* Just under 50 per cent.

469. Just under 50 per cent?

*(*Mr *Grayson.)* May I say, when you say custodian, we are directly concerned with forests we own as the state forestry enterprise. As the Forestry Commission we are concerned with what is happening on other areas and are closely in touch with companies which manage those areas.

470. Let me see, 50 per cent would be that which you own or that with which you have some responsibility?

*(*Mr *Grayson.)* Oh, directly 50 per cent because we own it, as well as having contact with people and responsibility on matters of research and monitoring and so forth for the whole forest estate of the country.

471. By any early test you are really a majority steward of our trees?

*(*Mr *Grayson.)* Yes.

472. To state the obvious, to seek your reaction for the record, if there were sinister developments going on right now, if anybody ought to be worried, it ought to be you?

*(*Mr *Grayson.)* Absolutely correct.

473. If anything serious goes wrong within the next couple of years—and you have explored no more than explored at present—then you think then the discomfiture will be your's?

*(*Mr *Grayson.)* Indeed.

474. Right, let me turn to this next question, I have tried on others—and I am a non expert—since you are our visiting experts I cannot resist asking you: it seems to me that the very growth of the tree takes alkali out of the ground, makes the surrounding ground more acidic and to that extent every tree as it matures becomes a stick of alkali. In a normal forest when it dies it crashes to the ground and returns the alkali, in a cultured forest, stewarded by man, the sticks of alkali are taken away ergo does not that follow that the soil of cultured forests must get more and more acidic, is that not pure logic?

*(*Mr *Grayson.)* Can I ask Dr Binns to answer as the chemical expert?

*(*Dr *Binns.)* Yes, Mr Taylor, I think it is a little incorrect to say it is a stick of alkali. It takes up acidic substances as well. It is an imbalance and more bases or alkalis are taken up.

475. On balance?

*(*Dr *Binns.)* Yes, it is not quite as extreme as you state. There is a steady drain, particularly of calcium and magnesium on the soil due to harvesting.

[Mr Taylor *Contd.*]

476. Yes?

*(*Dr *Binns.)* This, I suppose, is one of the reasons why we would like the parts of the trees which contain the highest proportions in terms of concentration and amount—that is the bark, branches, twigs, needles and leaves—to remain in the forest rather than being taken out. Many years ago it was calculated that with the exception of phosphorus, nutrient losses in normal harvesting, were made good by natural or manmade inputs. That does not answer the acidification point you put. There is in the soil a small increase in acidity consequent on harvesting. One would normally expect this to be made good by the mobilisation of nutrients from rocks, natural weathering processes. I think the question implicit in this is that if there was increased acidification as well, that might make those processes fail to operate, I think this is the point that has been made by some people.

477. I would not be saying anything very new if I said in an area of acidic rainfall, not the most extreme but above the norm, where there was active energetic foresting by man, there is bound to be a tendency for the soil to be more acidic?

*(*Dr *Binns.)* Yes, I think one should add this would apply whether there were conifers or broadleaves, the same drain, the same imbalance occurs.

478. Right. May I turn to one more question, one of the things that interested me a lot when we were in Norway was apparently in their folklore, in their naming of their environment there are literally countless dead fish lakes so called in the Norwegian local names, indigenous names, that go back for generations, if not for hundreds of years, countless dead fish lakes. I would like to know from you, as experts, in shifting from fresh water to forests, is there a sort of historic pattern of unexplained setbacks in the major forest areas of Western Europe? Is it something that in Medieval times every so often there was a plague, is it through all the trees, historically, they have unexplained periods of retrenchment and suffering, is that anywhere in the records or folklore?

*(*Dr *Binns.)* Only as far as the European Silver fir goes. I only know of these unexplained decline periods which are well documented in Germany.

479. What sort of rhythm, have you got?

*(*Dr *Binns.)* The dates I have are the 1850s, 1890s and 1920s. 1922–23, if I remember rightly from the meteorological and historical records, was a very dry year.

480. It can be said all those dates, they have it in common, modern industrial era, do they have anything else in common?

*(*Dr *Binns.)* I do not know enough about it to answer.

481. I would be very interested if that question could be answered?

*(*Dr *Binns.)* I have written to my German colleagues and said do they look at meteorological records about the decline of European Silver fir to see whether they could find anything that would give them a lead from earlier periods, because one implication was given that this was an even older phenomenon in documentation.

482. Not even in folklore?

*(*Dr *Binns.)* Not that I know of.

Mr Jones

483. In reply to Mr Taylor a few moments ago, Dr Binns suggested the natural weathering process of the rocks made up for gradual acidification that resulted from the take up of alkalis, that was an average answer or was it related to areas of igneous rocks as well?

*(*Dr *Binns.)* That is an average answer, you are quite right, yes.

484. We would still expect a process of steady acidification of areas based on igneous rocks?

*(*Dr *Binns.)* If harvesting is what we are talking about, it must place a steady drain on the supply of calcium and magnesium, yes.

485. Could I go back to an answer Mr Grayson gave a few minutes ago about the loss of trees in Germany when he seemed to be minimising the damage and saying this had not resulted in any loss of cut as such primarily because they were taking down the older trees; now were they at the end of the period when they would normally fall due for cutting or were these older trees being chopped down a bit earlier? One of the contentions that has been put to us in Scandinavia is that foresters, private and public, are losing money by having to take

[Mr Jones *Contd.*]
their cut earlier in order to avoid a loss, full loss, when disease occurs?
(Mr *Grayson.*) I have no information on cutting in detail in other countries but my understanding on removal of trees which have discoloured and died is that they are at the higher end of the age range, but I am not even certain about that. Could I clarify the question of minimising? I would like to draw the attention of the Committee to Table 3 of Dr Binns' paper on page 11 where he talks about a survey for the whole of the country and it refers to millions of hectares. In the second column and under: "Severely damaged" it shows only 60,000 hectares were severely damaged. That does not mean that they were all brown and dead, it means there were trees within that area which died.
(Dr *Binns.*) It means the total sum of trees which were recorded as severely damaged, if put in one place would cover 60,000 hectares. The severely damaged trees are scattered throughout the stands to which they are referring. It is not to say that it is not serious, but you see very few areas of dead trees.

486. Could I ask also a supplementary question to something Mr Grayson said earlier on, when he said you were in close touch with what was going on overseas and with scientists in other countries, there is at the moment a conference in Munich which is billed as "the conference of all conferences on acid rain", do you have representatives at that?
(Mr *Grayson.*) No, I do not. I do not know what meeting is being referred to.
(Dr *Binns.*) This is a high level meeting, I believe the Department of Environment are represented.

Chairman

487. The Council of Ministers.
(Dr *Binns.*) The Department of Environment have sent people there.

Mr Jones

488. You will get feedback?
(Dr *Binns.*) Yes.

Mr Chapman

489. Your sponsoring Department is the Scottish Office, is that right?
(Mr *Grayson.*) No, we go to the Treasury for funds. We are responsible to three Ministers and the lead Minister for forestry matters in this administration is the Secretary of State for Scotland but we are a department in our own right.

490. The reason I asked that is for two purposes, one is to say I put down a question to the Minister for Agriculture....
(Mr *Grayson.*) Yes.

491. About a report you brought out about broadleaved trees and it was transferred to the Scottish Office; it was not on acid rain I hasten to say, Mr Chairman. It does raise the point there seems to be a division of responsibility in relation to forestry policy as between the Scottish office—from my experience—the Department of Environment and MAFF?
(Mr *Grayson.*) I do not think we are finding any differences of view in matters of acid rain. We are closely in touch with DOE's chief scientist. We are talking to officials rather than Ministers on this matter. On the other matter, I think it must have gone up to the Secretary of State's office because, as I said, Mr Younger tends to lead on national matters and as this is a national broadleaved policy matter it would come across to us from his private secretary.

Mr Smith

492. I wonder if I could tackle you again on Germany, and particularly on Table 3 in Dr Binns' pamphlet, because the figures that you have drawn our attention to there differ very dramatically from the figures which *we* received when we were in Germany. Therefore, I want to ask you two specific questions. Firstly, who is "Anon."; who drew up this table? Secondly, what do you precisely mean by "'new' forest damage"?
(Dr *Binns.*) I can answer that directly. "'New' forest damage" is "Neuartige Waldschäden" which is the German word they use to describe it. That is the heading from their own table in the official report which, if we look, is reference 6 in the references. That table is taken directly from the official German report for 1983.

493. Have you inquired as to what precisely it means?
(Dr *Binns.*) What precisely *what* means, I am sorry?

[Mr Smith *Contd.*]

494. What exactly " 'new' damage" is. Is it damage that has only appeared in the last six months, or what?

(Dr *Binns.)* No. It means a new *kind* of forest damage. That is what the German means literally. However, it seemed clumsy to put it into English in that way. It was thought wise to put it in inverted commas over that table. They call it the new kind of forest damage, not what appeared in 1983 or 1982 or what might appear in 1984.

Mr Taylor

495. What is the German for it?

(Dr *Binns.)* "Neuartige Waldschäden".

Mr. Taylor: Thank you.

Mr Chapman

496. Could I follow up what Mr Smith says? When we were over there—and this refers to test areas or sample areas in the Black Forest—we were told that in 1981 eight per cent of the trees examined in those areas were found to be diseased seriously or slightly—mostly slightly—but the following year it had gone up to about 38 per cent—which they felt may have been a slight over-estimate—and last year—1983—it had topped 50 per cent. In no way do those figures begin to be reconciled with the figures in Table 3. What is your comment on what?

(Dr *Binns.)* I am sorry to disagree, but the figures in Table 3 are for the *whole* of West Germany, and they are taken from their official report, which is the Federal Government's report on forest damage for the whole of Germany. It may well be that in the Black Forest area the figures are different. That is a summary for all the *Länder* in Germany.

Chairman

497. You do not know the Black Forest figures separately?

(Dr *Binns.)* I do not have them in my head, I am sorry. They are available, certainly. The report to which I refer there has the figures for all the separate *Länder.* If I have a moment, I may have here another paper which has one of those tables in it.

Mr Chapman: If it has got Baden-Württemberg in that table, that would be interesting.

Mr Smith

498. If these are figures for the whole of Germany, where everyone acknowledges that there are large areas of German forest that are not affected at all, but there are other areas which are severely affected, could I ask why it is that you chose to put in here the figures for the *whole* of Germany rather than for the damaged areas?

(Dr *Binns.)* That is very simple indeed: because this paper was written for British foresters, to give them an insight into the problem of acid rain.

499. Do you feel that choosing *those* particular figures gives a better insight?

(Dr *Binns.)* I think it is a perfectly adequate introduction to the problem, yes. I have the figures here for Baden-Württemberg, if you want them. The 1983 survey was of the 1.3 million hectares (which is 18 per cent of German forests) that are in Baden-Württemberg, and 49 per cent of their area was damaged—just under half—all categories. I do not have the breakdown into categories for the *Land* itself, I am afraid, but I do not think it differs dramatically (if I remember correctly) from the figures for all the other states, for the whole of Germany. That is, a small percentage of heavily damaged, a medium percentage of moderately damaged and a large percentage of slightly damaged. Further figures show that a quarter of the damaged area for the whole of West Germany is in Baden-Württemberg.

Chairman

500. Dr Binns, a little earlier you told me that it was not your responsibility or the Forestry Commission's responsibility to carry out monitoring of the atmosphere. I understand that. Do you carry out any laboratory experiments at all, as to the possible effects of pollution and pollutants on trees?

(Dr *Binns.)* No, we have not done any so far. We have been aiding other organisations, particularly Imperial College who are doing the experiments, by supplying them with lots of different species of trees, including clonal stock to improve the precision of their experiments.

501. So you are in close touch with experiments that are taking place?

(Dr *Binns.)* Yes.

[Chairman *Contd.*]

502. Can you tell me, what is the longest exposure, in these experiments, of trees to SO_2 and NO_x? Is it a matter of months or years?

(Dr *Binns.*) It is a matter of months, I think, partly because of the difficulty of growing trees for any length of time in rather small environment chambers. Most of these have been designed for annual crops which do not grow very tall.

503. So we have no experiments on the long-term effects?

(Dr *Binns.*) No. I think some work has been done by Imperial College on Scots pine, which went on for about two years, but that must be about the longest.

504. On page 8 of your printed paper "The Effects of Pollutants on Soils", you say there, in the second sentence: "Nevertheless, the long-term effect of continued loading of soils with more than normally acid precipitation is of concern,". Could you elaborate on that? How is it of concern, and what evidence is there to support your concern in the United Kingdom?

(Dr *Binns.*) Not very much, I think. It is taking note of the observations made in other countries, particularly in Scandinavia, about the effects on the environment there; the concern of *their* scientists—in Norway, for example, certainly, as well as Sweden—that there will be long-term damage to the soil, with the continued loss of bases due to the increased rate of leaching from more than normally acid rain. It is in that sense that there is a concern here that it might cause long-term changes which could be deleterious.

505. Thank you. The converse of that, in a sense, I seem to find on page 14, in the middle of the paragraph that is headed "British Forests and Acid Depositions", where you speak of the experiments carried out in the Southern Pennines where most had failed until recently. Since the mid-1970s, you go on to say, you have had success and you have come to the conclusion that you are being successful in growing trees there now because of the reduction both in smoke and SO_2. That would seem to indicate that where there is a cessation or a diminution of precipitation of certainly sulphur anyway (because that is the one you refer to), conditions improve in so far as the growing of trees is concerned?

(Dr *Binns.*) Yes.

506. Would it be valid, then, to say that if that is the case, where there is an *increase* in acid precipitation one can expect the prospect of trees to grow less?

(Dr *Binns.*) The only point here is that this is, of course, dry deposition we are talking about, and not wet deposition.

507. I know, but we are concerned with both.

(Dr *Binns.*) Yes. It would depend on the degree, I think. There is no doubt that that area was exceptionally heavily polluted, judging by the way our fences fell to pieces in about 18 months, with the zinc coating on them coming off and rotting away. That, incidentally, has now changed, and they last a few years now, even though the zinc coating is, I am sure, much thinner than it used to be 20 years ago. I am not sure that you can compare the very heavy loadings of dry deposition in that area with the *acid* depositions, including a lot of *wet* deposition, in other parts of the country where the concentrations are much lower although the total hydrogen ion load may be quite high. This is one of the points which is at issue, I think. That is, which is more important—a large amount of somewhat acid rain, or of rather smaller amounts of much more acid rain? It is the East Scotland versus West Scotland contrast, more acid in the East (4.2 pH), less acid in the West (4.7, 4.8 pH). However, the difference in geology unfortunately makes any comparison of these effects very difficult.

(Mr *Grayson.*) I think you have touched on a very difficult point. That is, that we have had a large-scale experiment created by the introduction of the Smoke Control Act in the late 1950s, after there had been the Beaver report. We have not got that possibility, I think, with long-range acid deposition of the wet kind, owing to the diversity of sources from which it may come. This is possibly not so serious a problem in Britain if we were to have adequate measures of controlling sources of emission, because the bulk of the deposition in Britain is from British sources. Nevertheless, it does remain an awkward difficulty that we cannot have that kind of demonstration. The basis of some of our difficulties is establishing a proper monitoring system for judging the effects of pollution arises because they *are* widespread, and over conditions of soil, species, elevation and so on, that are very diverse.

[Chairman *Contd.*]

508. I wonder if you can help me on this, because I do not understand the position in the Pennines. What you are saying would seem to indicate that the moment you stop depositing as much dry acid as you have done in the past, some reversal process seems to take place, because you can now grow trees where you could *not* grow trees. Does that mean that there is something in the soil that is now neutralising the acid, that has been deposited there for many generations? The evidence that we received when we were in Norway, where quite a lot of experiments going back to 1927 had been taking place in *some* forest areas, showed that once you had leached out your neutralising agents in the soil and they were gone, the acid was cumulative, and even if you stopped putting acid there, your soil remained acid. What is your comment on that?

*(*Dr *Binns.)* I think the point is that the agents would act directly on the foliage of the plants and not on the soil. The needles are killed or damaged by the gaseous SO_2, or the particles that have settled on the needles, if you like, but not through the roots. When you remove the damaging substances from the air, or lessen the quantity below certain thresholds, then the trees are able to grow. At least, that is how I interpret the results that we have got, where not only the trees in the new experiments grow, but the old ones—trees that have sat looking miserable and hardly growing at all for 20 years—have now started to grow.

509. Have you carried out experiments into the composition of the humus and subsoil?

*(*Dr *Binns.)* No, I have not. These are not my experiments. These are results from my colleagues in our Northern station. I have not looked at the details of the soils.

510. So you really cannot answer my question?

*(*Dr *Binns.)* No.

Mr Smith

511. Have you or your colleagues, in connection with that, done any measuring of levels of ozone, any assessment of the photo-chemical effects, disappearance of smoke, or anything of that kind?

*(*Dr *Binns.)* Not of ozone. We did do measurements of SO_2, by means of lead candles in the 1950s and 1960s, and zinc plates as well, in those areas.

512. Are you doing anywhere in the country any assessments of the effects of ozone on trees?

*(*Dr *Binns.)* No.

513. None at all?

*(*Dr *Binns.)* The Commission is not, no.

Chairman

514. To follow my line of questioning, you have no idea of the significance of acid deposition in the leaching out of essential nutrients from the soil?

*(*Dr *Binns.)* It is a very difficult question to answer. In my discussions I have had with chemists working for the Institute and for other organisations we think that the processes are quite slow and that at least one or two of them are strongly of the opinion that unless the pH of the rain is very low it has very little effect because the acidity of many of these soils is already quite low.

515. You are confusing me. You talk of the pH being low, by which you mean the soil is extremely acid, and then in the same breath you talk about the acidity of the soil being low, which is a contradiction in terms.

*(*Dr *Binns.)* That was a slip of the tongue, Chairman, and I apologise. If we have a soil which has, shall we say, a pH of 4.5, which is quite possible in the humus of the upper layers of many uplands areas with acid lakes, and we have rain with a pH of 4.7 falling on it, chemical law suggests that there will be no effect in terms of acidification because the rain is less acid than the soil on which it is falling. However, there is a fair load of acid coming in and the arguments I think are about what actually happens as a consequence of this, and the evidence seems to be unclear. I have asked colleagues whether we ought not to do some laboratory studies and have other organisations as well as ours to look at the difference between these sorts of effects of small amounts of very acid rain and large amounts of not so acid rain, which can be less acid than the soil on which it falls.

Mr Jones

516. A moment ago you pointed towards the difficulty of understanding whether it was the total acid or the acidity of the rain

[Mr Jones *Contd.*]
or indeed anything else that made the difference. Could I ask you as a chemist whether, since all this is based on the assumption that we are looking at the pH of the soil and the rain, in fact whether total titratable acidity would in fact be a more relevant measurement?

(Dr *Binns.*) I am not a chemist incidentally but I have some chemical knowledge. It might well be. I think there are difficulties here about deciding what we ought to measure, and how we ought to measure it. You are talking about the soil I assume. That might well be more easy to measure, but it may not be so easy to do in some remote areas where it is often a problem.

Chairman

517. I have only one question left that I wish to ask you, Mr Grayson, and that relates to the Community Document 8125/83, which I think you sent us with your original typed copy of the paper. That document appears to require forest monitoring. Can you tell me to what extent we can be said to be complying with the requirement of that Directive or how far we would have to go to do what they ask?

(Mr *Grayson.*) Could I say, Chairman, that the whole thing is at a very early stage of discussion and it seems not to be concerned with the technical aspects of the matter but very much more with the legal and financial and administrative aspects of the whole subject. There are difficulties centred on the issue of trying to combine two such disparate subjects together in one draft Regulation as this, as well as the *vires*. So it has not got down to the point of technically determining how much monitoring would be required and so forth. I ought to say a meeting to which Dr Binns referred earlier, the one to which he went last week, was in fact to a different body, namely, the UNECE—United Nations Economic Commission for Europe—and it was concerned very much with this question of monitoring. We have just been agreeing with other member countries, which include eastern European countries as well, guidelines to which we aim to work, and we shall be setting up monitoring as a result of that. So I think that is leading the Community initiative at the moment.

Chairman: There are no further questions. May I thank you, Mr Grayson and Dr Binns and colleague for coming this afternoon.

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WEDNESDAY 27 JUNE 1984

Members present:

Sir Hugh Rossi, in the Chair

Mr David Alton	Mr Norman Miscampbell
Mr Sydney Chapman	Mr Chris Smith
Sir Reginald Eyre	Mr John M Taylor

Memorandum submitted by the Natural Environment Research Council

ACID RAIN

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The cost of printing and publishing these Minutes of Evidence is estimated by Her Majesty's Stationery Office at £4,500.

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INTRODUCTION

1. *Role of the Natural Environment Research Council (NERC)*

1.1. The Council is responsible for the support and conduct of research and postgraduate training in the physical and biological sciences of the natural environment, including studies of interactions between organisms and the environment, and of environmental processes and their perturbation by the activities of Man(1). The Council's charter refers, amongst other things, to research in meteorology, hydrology, hydrogeology, the earth sciences, terrestrial and freshwater ecology, forestry, fisheries and conservation.

1.2. The Council's remit is a broad one and it includes research on both the effects of pollution upon the environment, and the interactions between pollution, natural changes in the environment, and Man's uses of his natural resources. Thus, while Council is not responsible for routine monitoring of pollution, nor for research into the emission and technical control of pollutants, nor for the advocation of particular control policies, it is necessarily concerned with research into the pathways and effects of pollutants, and with the independent assessment of the environmental implications of past, present and future control policies(2–3).

1.3. The NERC's involvement on research in pollution covers all aspects of the deposition, pathways and effects of pollutants in terrestrial and aquatic systems with particular reference to effects on forests, seminatural systems (eg uplands), aquatic biota including fisheries, and water catchment(2–4). In the case of atmospheric pollution, including acid rain, the Council has also assumed from the Agriculture and Food Research Council (AFRC), much of the responsibility for research into the effects of pollutants upon crop plants and agricultural systems. The roles of the individual Research Councils in this and other areas of pollution research, are described elsewhere(4–5).

2. *The Council and its Committees*

2.1. The House of Commons Committee is referred to the Council's Annual Report(1) and to evidence submitted to other Select Committees(6–7) for details of the structure and research activities of the NERC. A brief summary is appended to this paper for the information of the Committee (Appendix I).

CURRENT NERC RESEARCH ACTIVITIES RELATING TO ACID RAIN

3. *Acknowledgements*

3.1. The Council gratefully acknowledges the contributions made to this paper by scientists in institutes, grant-aided laboratories and universities sponsored by the NERC and its customers (Table 1). The services of these and other scientists in NERC are available to the Committee, if so required. It is emphasised, however, that the views expressed in this paper are those of the Council and are made without prejudice to the views of the individual scientists, NERC establishments, customer organisations and other bodies mentioned below.

4. *General Considerations*

4.1. The Committee will be well aware of two popular misconceptions about acid rain. The first arises essentially from the belief that the acid in rain derives solely from emissions of sulphur dioxide (SO_2) and other sulphur compounds from power generating stations. There are in fact, many other mobile and static sources of such emissions. Furthermore, emissions of nitrogen oxides (NO_x) and other nitrogen compounds account for almost a third of the acid in rain. Emissions of hydrogen chloride (HCl) may also contribute some hydrogen ions to the atmosphere.

4.2. The second misconception is that acids in wet precipitation (acid rain) are the only cause for concern. In fact, dry deposition of SO_2, NO_x and other acid gases and particulates may contribute up to 70 per cent of the total acid deposited in the UK. It is preferable, therefore, to talk of "acid deposition" rather than acid rain.

4.3. Any examination of the direct effects of acid deposition upon forests species, crop cultivars and other plant species also involves consideration of ozone (O_3); peroxacetyl nitrates (PAN) and other oxidant pollutants most of which are derived from NO_x and hydrocarbons by photo-oxidation in the atmosphere. Oxidants may affects plant life directly either alone or in combination with acid deposition and/or with other stresses such as drought and disease. Acid deposition, having passed through plant canopies and into the soil, may influence plant growth indirectly by affecting the chemistry and microbiology of the soil, thus altering essential processes of plant nutrition. At the same time, mineralisation and leaching processes result in the release of calcium, sulphur, aluminium and other elements into the pore waters of the soil, especially in acid soils on base-poor (low calcium) bedrocks.

4.4. The geochemistry of soils, subject to acidification, is complex as is the impact of elements released by leaching and drainage to surface and groundwater. In surface waters, there are complex questions of chemistry and toxicology to be resolved. For instance, do fish populations succumb more easily to episodes or flushes of toxic elements rather than to gradual acidification of streams and lakes?

4.5. Most of the above issues may be considered to fall within the strict definition of acid precipitation research. The various components of current and planned NERC work which are discussed below, fall mostly into this category. However, wider issues such as the interactions between acid precipitation and other causes of environmental acidification (eg afforestation, some aspects of upland improvement) are also of great concern to the Council and are discussed, but not necessarily costed, where relevant.

4.6. Apart from the problem of defining what is, and what is not research on acid precipitation, the Council is also faced with a rapid expansion of interest in the subject by its own members and by its customers. Consideration is being given within the NERC, for instance, to new Science Budget work on fundamental processes involving acid species in the troposphere, and to expanded interdisciplinary research on the geology, geochemistry, hydrogeology, hydrology, freshwater biology, soils, terrestrial ecology and acid precipitation of the UK to identify areas which may be most "at risk" from acidification. Many existing Science Budget and commissioned projects are being reorientated towards understanding acidification and related processes. Negotiations are also in hand for new NERC research with support from the Department of the Environment (DOE), the EC and other agencies including regional water authorities. The Committee will appreciate, therefore, the uncertainties inherent in the estimates of total NERC effort in acid precipitation research (section 5).

5. *Current and Planned NERC Research*

5.1. The expenditure on NERC research relating to acid precipitation and acidification processes in 1982–83 was approximately £0.55m of which about £0.45m was from the Science Budget, divided equally between the institutes (primarily the Institute of Terrestrial Ecology (ITE) and the Freshwater Biological Association (FBA)) and the universities (grants and studentships). The estimated expenditure for 1983–84 indicates a substantial increase in effort on all fronts at c £0.93m including £0.67m from the Science Budget and £0.26m of commissions, mainly from the DOE and the EC. Other customers include the MAFF, and the Water Research Centre (WRC). The commissions, many of which commenced mostly in the latter half of 1983–84, include some substantial subcontracts to universities, supervised by the ITE.

5.2. It is difficult to forecast expenditure for 1984–85 but it is likely to be in the range £1.3m to £1.65m, divided roughly between the Science Budget and commissions in the ratio 4:3. At least 10 per cent of this effort is likely to be in the form of linked projects between institutes and universities involving subcontracts, and Special Topic awards and/or CASE studentships.

5.3. The main fields of NERC effort in 1983–84 are as follows: atmospheric processes including deposition processes (23 per cent); pathways in terrestrial ecosystems (10 per cent); effects on plants and soils (32 per cent); geology and hydrogeology (10 per cent); catchment studies (10 per cent); aquatic chemistry and biology (10 per cent); other studies (five per cent). These estimates exclude related work on, for instance, effects of afforestation and other forms of land management upon soils, drainage and the quantity, quality and biota of surface waters (est £0.52m in 1983–84). They exclude also support received directly by universities from Departments, the EC and other bodies, which may be deployed alongside NERC funds in support of broad programmes of research.

5.4. The broad estimates of effort given in the preceding paragraphs reflect both historical patterns in research and the need to meet objectives relating to problems of pollution other than those caused by acid deposition. This applies especially to studies of effects on plants where there is a long standing requirement for information about the direct effects of gaseous pollutants upon plant growth and productivity, forests and seminatural systems.

5.5. The year 1984–85 is likely to see increased effort on all fronts including fundamental research on atmospheric, deposition, soil and hydrogeological processes; on catchment studies; and on strategic/applied studies of air pollution effects upon plants and soils. The Council has yet to decide also its future investment in fundamental research on natural processes of cycling of elements such as nitrogen; processes which are intimately related to acidification problems(8). It is likely, for instance, that much more work on the natural origins of sulphur and nitrogen in the atmosphere (eg from oceans) and in soils (eg by mineralisation), and on the deposition and fluxes of gaseous ammonia in terrestrial ecosystems, will be required.

6. *Coordination with Other Bodies in Acid Rain Research*

6.1. Research on acid deposition embraces an enormous range of processes and environmental systems. In consequence, it also involves a great diversity of statutory bodies, including Departments, research organisations, and scientific and technical disciplines. The mechanisms of coordination are thus exceedingly complex and there are numerous types and forms of collaboration between organisations and individuals. The NERC's primary responsibilities are to its customers, notably the DOE to which the Council acts as advisor on many environmental research issues, and to the fulfilment of its charter responsibilities in postgraduate training and research. (Sections 1 and 2). The organisation of the Council and its committees ensures adequate cross representation of these interests (Appendix I). However, there are numerous mechanisms devised to ensure coordination and liaison at the working level (Appendix II).

6.2. We turn now to discuss the results of current work on acid precipitation in the principal main fields of research(11–16). Attention is drawn, where appropriate, to gaps in knowledge and to plans for remedying such deficiencies.

THE ATMOSPHERE

7. *General Considerations*

7.1. The Council devotes most of its resources to the study of the polluted environment and deposition processes at the air/land interface in the UK. However, these studies together with some other projects contribute useful information on the natural sources, background levels and trends in concentrations of sulphur and other elements in the atmosphere. The Council is also collaborating with the Science and Engineering Research

Council (SERC) and other bodies in a programme to strengthen work in the UK into fundamental processes of tropospheric chemistry.

8. *Natural Sources of Sulphur in the Global and European Environments*

8.1. The British Antarctic Survey (BAS) collaborates with various research institutions in international studies of ozone and other constituents of the atmosphere. Comparison of samples from the Antarctic and Greenland ice sheets indicates that there is a current anthropogenic input of sulphur and acid compounds to recent snow in Greenland of between one and two times greater than the natural input.

8.2. The origins of this natural input are uncertain but the Marine Biological Association (MBA) is mounting a pilot study of the emissions and fluxes of dimethyl sulphide and other sulphur compounds in European waters, including the Western Approaches and the North Sea. Extensive use is being made of remote sensing techniques. This work complements international research, some of it funded by industry, designed to quantify the natural sources and fluxes of sulphur compounds. Parallel work on the release of sulphur from bedrocks in the UK is proposed by the British Geological Survey (BGS) and ITE.

8.3. The Committee will no doubt receive evidence on various European studies, including the European Monitoring and Evaluation Programme (EMEP) and on studies of long range transport of sulphur emissions across the North Seas, from appropriate UK Departments and research organisations. The evidence will probably refer to "natural" contributions of sulphur of unknown origin (para 8.2). The NERC is not a major participant in such work although the results have been used to assess possible impacts of air pollution in W Europe(10).

9. *The UK Environment*

9.1. A wide range of sulphur and nitrogen compounds is transferred to vegetation and other surfaces by two processes:

i. dry deposition of gases (eg SO_2, NO_x, O_3) and particulates (eg acids, ammonium salts). The transfer of particles in the size range 0.1–1.0 μm (eg sulphates, nitrates) to surfaces is a much less efficient process than the dry deposition of gases;

ii. wet deposition of particulates and dissolved gases in rain, mists, hail and snow.

Most attention is paid at present to gaseous SO_2, NO_x and O_3, and to sulphates and nitrates in rain. However, interest in gaseous ammonia (NH_3) and acids (eg nitric acid—HNO_3) is increasing.

9.2. The balance of wet to dry deposition differs markedly between regions (eg, urban and rural) and between countries (eg, Norway and Sweden *v* Central Europe). The composition of pollutants, notably the gases, at any one site is also in a constant state of flux. It is necessary, therefore, to characterise the environment before considering the fate and the effects of its constituent pollutants. However, the broad trends in emissions and in the atmospheric concentration of pollutants in the UK can be ascertained from official and research publications(3,16).

9.3. *Dry Deposition.* The total emissions of SO_2 and smoke have decreased by about 15 per cent and 60 per cent respectively, in the period 1970–80. The corresponding decreases in ground level concentrations in urban areas are 40 per cent and 50 per cent respectively. Data for rural areas are sparse but one might assume proportionate reductions including 15 per cent for ground level concentrations of SO_2. Fowler (1984) has estimated the dry deposition of SO_2 within Britain to range from 8g $SO_2/m^{-2}\,yr^{-1}$ in the industrial heartland to 0–1g $SO_2\,m^{-2}\,yr^{-1}$ in North West Scotland. These estimates are consistent generally with data on domestic and industrial emissions, and with improved dispersion of emissions from taller and more efficient chimneys.

9.4. Emissions of NO_x are known to have increased in the period 1950–70 but the changes appear to have been less significant over the last decade(1,16). It is believed that emissions from motor vehicles increased significantly compared with those from other sources in the period 1970–80. However, emission and especially monitoring data for NO_x are sparse. Denitrification processes in soils may also contribute to NO_x concentrations in rural areas where trends may differ from those in urban areas. The mean annual concentration of NO_x in rural areas is typically in the range four to seven parts per billion (8 to 14 $\mu g\ m^3$). The calculated deposition velocities for NO_2 and NO are reported elsewhere(8).

9.5. Work, mainly at Imperial College, indicates that the natural background concentrations of 20–80 $\mu g\ O_3\ m^{-3}$ are sometimes exceeded to an extent that can damage sensitive plants in the UK. Such events may occur over large parts of Europe where the potential for phytotoxic concentrations to develop in stable weather conditions is significantly greater than in the UK. Very little work has been done to determine the impact of other, secondary pollutants in the UK but peroxyacetyl nitrate (PAN), a constituent of "Los Angeles Smog", has been detected over southern England in stable air masses on hot sunny days.

9.6. *Temporal and Spatial Variations in Gaseous Pollution.* Recent observations by ITE(16) and other bodies in the UK and overseas reveal a complex and changing mixture of pollutants, even in rural atmospheres. Daily concentrations of SO_2 in northern Britain are maximal at 10.00 hrs GMT and minimal at 15.00–18.00 hrs. This pattern is often matched in proportion by the fluctuations in mean concentrations of NO_2 and NO. In contrast, concentrations of O_3 are maximal at 15.00 hrs and minimal at 08.00 hrs. The peak monthly concentrations of SO_2 occur in northern Britain in January/February; those of NO_x in September/November; and those of O_3 in April/June.

9.7. The broad patterns of SO_2, NO_x and O_3 pollution discussed above are probably not atypical for much of the UK and for western Europe for most of the year. However, more intensive monitoring is required to confirm this assumption and also to determine the conditions under which peak concentrations of SO_2, NO_x and O_3 are likely to coincide. The coincidence of an O_3 episode (eg 200 $\mu g\ m^{-3}$ for six hours) with shorter term peak concentrations of SO_2 and NO_x, may be a major cause of damage to trees and other plants, in some areas.

9.8. It is dangerous to extrapolate from the data available for SO_2, NO_x and O_3 concentrations in urban and rural areas; the rural data are especially sparse. Nevertheless, it is estimated that 10 million hectares of Britain (total—23 million hectares) are subject to mixtures of SO_2 and NO_2 with annual means in excess of 30 and 25 $\mu g\ m^{-3}$, respectively. Approximately, 2.3 million hectares are exposed to 50 $\mu g\ SO_2$ and 40 $\mu g\ NO_2\ m^{-3}$, and 240,000 hectares to 100 $\mu g\ SO_2$ and 80 $\mu g\ NO_2\ m^{-3}$. The areas exposed to significantly elevated concentrations of O_3 vary enormously in size and location, and from year to year.

9.9. *Wet Deposition.* We have mentioned already the variation that occurs in the contributions of dry and wet depositions to total inputs of acid deposition in different parts of the UK, and indeed between different countries in western Europe. Dry deposition is most important near connurbations, whereas wet deposition gains in importance in areas where the annual rainfall is heavy. Most of the data on wet deposition is concerned with acid in rain. Even so, there is a dearth of long runs of reliable monitoring data, and the coverage of existing monitoring systems in the UK is patchy(9,16). Much less is known about the contributions of snow, hail, and mists to total acid deposition, notably in upland areas. Broadly speaking, however, the following conclusions appear to be reasonable.

9.10. In northern Britain, the average weighted acidity of rainfall is 60 $\mu eq\ H^+ l$ (pH 4.2) in the east, and 25 $\mu eq\ H^+ l$ (pH 4.6) in the west. These figures are comparable with those recorded in southern Scandinavia and the north eastern areas of Canada and the USA. The probability of a rainfall event with a low pH value (eg, pH 3.0) is greater in a location with a mean pH value of 4.2 in rain, than in a location with a mean value of pH 4.6. On occasions the pH of incident rain may be as low as 2.9 (1,200 $\mu eq\ H^+ l$). Rain tends generally to be more acid in the period April to June than at other times of the year.

9.11. The analysis of trajectories of air masses over Scotland indicates that acid episodes of rain occur when the air masses arrive from western Russia, Poland, Germany, France, Czechoslovakia and England, and that relatively clean rain arrives in air masses from the North Atlantic. The pattern of deposited acid (the product of H^+ ion concentrations and amount of rain), is thus complex. The largest amounts of acid deposited by wet precipitation are found in high rainfall, high altitude areas *viz* the Lake District of England, the southern uplands and the west central Highlands of Scotland. These are areas where soils are thin and acid, usually overlying slowly weathered bedrock (eg gneiss, granite, porphyries) and likely to be "sensitive" to acidification in the absence of intensive management.

9.12. Information on the chemistry of rain is sparse but in northern Britain, sulphuric and nitric acids (the oxidation products of SO_2 and NO_x) contribute 70 per cent and 30 per cent of the acid in wet deposition. In addition, hydrogen chloride (HCl) and ammonium salts are present in appreciable quantities. The contributions of snow, hail and mist to acid deposition remain uncertain; more work is needed. However, evidence from Scandinavia suggests that most of the acid ions in snow are removed in the early stages of snow-melt which may achieve pH values of 3.2.

9.13. The preceding paragraphs raise a number of issues in need of attention and research in respect of atmospheric processes including the monitoring and measurement of wet and dry deposition. The Council is actively engaged in discussions with the DOE, EC and other bodies about the development of new programmes of research on such issues in the UK and in Europe. Examples include:

i. extension of systems to monitor SO_2, NO_x, O_3 and other gaseous pollutants in rural areas;

ii. extension of systems to monitor wet precipitation with particular reference to the determination of long term trends in H^+ deposition; to the contributions of oxidation products of SO_2, NO_x and other acid compounds; and to the frequency and distribution of acid rain "events";

iii. deposition of acids in mists and snow in upland areas, including the chemistry of solutes in snow and snow-melt;

iv. deposition and fluxes of oxides of nitrogen and of ammonia above vegetation and soils;

v. fundamental chemistry of H^+ and OH^- nuclides in clear and polluted air masses of the troposphere.

Some projects are already underway and others will be initiated in 1984–85.

PATHWAYS AND EFFECTS IN TERRESTRIAL ECOSYSTEMS

10.1. *Deposition and Pathways.* We have indicated already that it is essential to characterise the environment at the interface between the atmosphere on the one hand, and plant and soil surfaces on the other. Only then will it be possible to determine the true impact of acid deposition and other pollutants upon the environment. Detailed work on the deposition on, and fluxes of SO_2 above forest canopies, crops and grasslands have been carried out by the ITE, the Atomic Energy Research Establishments (AERE) and others. Much less is known about NO_x, O_3, NH_3 and particulates including mists but work is in hand or planned to remedy these deficiencies. Further work is also needed on the characteristics and processes of wet precipitation of pollutants in rain and snow.

10.2. Such detailed studies must, ultimately, be extrapolated to the UK as a whole. The deficiencies of existing monitoring systems in terms of sampling technologies, location of sampling sites and frequencies of sampling are well known(3,9). The UK monitoring networks relevant to acid deposition are being reviewed by the DOE. It is pertinent to note, however, that plant communities receive both wet and dry deposition which, in the case of acidic compounds, can be translated into total inputs and throughputs of their components (eg, $SO_4 = H^+$, NO_3^- ions).

10.3. There is evidence from ITE and elsewhere of modifications to the chemical composition of rain falling on evergreen and deciduous forests and passing to the ground as throughfall and stemflow. These modifications involve not only the removal of surface products of dry deposition by wet precipitation, but also some considerable leaching of inherent plant materials from foliage. At one evergreen site, the acidity of incident rain changed from pH 4.2 to pH 3.4 in throughfall, and to pH 3.3 in stemflow. Similar changes have been recorded in stands of Sitka spruce over 25 years old. However, there seems to be considerable variation between species, and possibly between stands of a single species but of different ages.

10.4. The effects of these increases in the acidity of rainwater passing into soils are only now being investigated as are the relative roles of wet and dry deposition, and of leaching of plant substances. Initial data suggest that the low concentrations of SO_2 and NO_x in rural areas may be of more significance than previously expected. It is pertinent to note here that the pathways of pollutants in terrestrial systems may be looked at in terms of elemental inputs and nutrient balances in plant and soil. Such work has been pursued in various ways on cereals and grasses at the University of Nottingham and the Grassland Research Institute (GRI), respectively. There are, however, still some problems to resolve in comparing the responses of lowland agricultural systems (fast growth) with upland (slow growth) systems, to atmospheric pollutants.

10.5. *Effects upon Plant Life.* It is convenient to consider the impacts of acid deposition upon plant life in terms of (a) direct, and (b) indirect effects. However, the two effects may occur concurrently and as a result of the same form of pollution. The identification of these effects is a difficult task given that the symptoms of injury are not discrete.

10.6. Research, done mostly in the UK, has shown that plant growth can be decreased in the presence of pollutant gases, without the appearance of obvious injury to foliage. Much depends upon the rate of growth of the plants, those under optimal (lowland) conditions appearing to be much less sensitive to prolonged exposure to low concentrations of SO_2 than are plants growing slowly under stressed conditions.

10.7. Work at Imperial College has shown that, under certain climatic conditions, episodes of ozone pollution may occur in summer months over parts of the UK and Europe in concentrations sufficient to cause visible injury and reductions in growth of sensitive cultivars and native plants. It has been found also that the impact of mixtures of pollutants cannot be predicted from the effects of exposures to single pollutants. Further complications arise in respect of interactions between pollutants and environmental stresses, especially drought and wind speed or exposure. Much of the research in this field, has been done at Lancaster University, Imperial College, Nottingham University, Newcastle University and ITE.

10.8. Work at Lancaster has concentrated on the interactive effective of SO_2 and NO_2 gases above 40ppb; concentrations which occur in many areas of Western Europe, affecting c.1 million hectares of rural land. The responses of plants to these levels of pollution vary with species, plant age and environment. Experiments under carefully controlled conditions using uniform plants of the same age, have demonstrated a beneficial response to SO_2 and NO_2 at low concentrations, and a sharp transition to adverse response as concentrations rise(11). The combined action of SO_2 and NO_x is often, but not necessarily, greater than the sum of their separate effects. Also, while deposition rates are constant, the uptake of the pollutants varies with environmental conditions. Nonetheless, some generalisations are possible. For some species, seedlings are more sensitive than adult plants, and effects are more pronounced when growth is slow. Low light intensities, short days and low temperatures increase both sensitivity and adverse effects.

10.9. At present, predictions of economic losses due to SO_2 and NO_x fumigations are hazardous but some deciduous trees appear to be more sensitive than herbaceous plants because growth is inhibited in spring and summer by concentrations of pollution which do not affect grasses and cereals. Damage intensifies in the second season implying a cumulative affect. Some pasture grasses, although sensitive in winter, show a remarkable capacity to recover in the summer; most cereals appear to be more resistant than pasture grasses. Both facts suggest some inadvertent selection of resistance during breeding and field trials of modern cultivars.

10.10. Apart from inhibitions of plant growth, there are important changes in the nature of growth. For instance, exposure to SO_2 and NO_2 inhibits root growth and increases shoot dry matter. The inhibition of root growth could be ascribed incorrectly to indirect effects of acid precipitation upon soil and root processes, including plant nutrition. There are close similarities in this response to SO_2 and NO_2 pollution with responses to O_3 pollution which have been studied at Imperial College. Both also affect photosynthetic processes which rely upon the precise control of cellular activity. Consequently, work is in hand to measure precisely acidity and $SO_4{=}$ions in cells in plants exposed to dry and wet deposition of sulphur, nitrogen and ozone pollution. Another priority at Lancaster is to verify observations which indicate elevated sensitivity to pollution amongst plants exposed to drought and extreme cold.

10.11. Surprisingly little is known about the effects of ambient concentrations of pollutants in the field in the UK and elsewhere. Nevertheless, Scots Pine used to be restricted in its distribution by pollution associated with concentrations of SO_2 at 100 $\mu g\ SO_2\ m^{-3}\ l^{-1}$, and excluded from areas at 250 $\mu g\ SO_2\ m^{-3}\ l^{-1}$ or greater on the Peninnes. Somewhat similar data exist for Germany. We have indicated also the work on ozone impacts in the UK.

10.12. The general conclusion of the work in NERC and elsewhere is that effects in the field cannot be reproduced convincingly in the laboratory by injecting single pollutants into clean, filtered air. The "ambient" environment of mixed pollutants must be reproduced experimentally and must include either the exclusion of and/or the amplification of selected pollutants. It is now realised that SO_2, NO_x, O_3 and possibly other gaseous pollutants (eg, hydrocarbons, hydrogen fluoride) must be included in dry deposition studies. Eventually these must include acid precipitation (mists and rain). Furthermore, it is essential to reproduce in such experiments typical diurnal and seasonal variations in both pollution and environmental variables.

10.13. Many attempts have been made to tackle these problems in whole or in part using laboratory, glasshouse and field fumigation systems of various designs. Nottingham and the Central Electricity Research Laboratories (CERL) have opted for carefully engineered field systems which amplify ambient concentrations by the controlled release of pollutants. ITE, Imperial College, CERL and Rothamsted have also developed chambers, based on the US "open top" chamber system, to exclude and also to amplify ambient concentrations by injection of pollutants. Both approaches have their limitations but both are under further development. The "open top" system is scheduled for further development in collaboration with member states of the European Community under CEC co-ordination, and with the US Environmental Protection Agency (EPA).

10.14. It is pertinent at this point to raise again the question of the extent of O_3 pollution and its implications for plant life in Europe. This compound is a secondary pollutant derived by photo-oxidation in the atmosphere of emissions of hydrocarbons and NO_x. Many of the incidents of damage to forests in Europe, notably Germany, include symptoms characteristic of ozone pollution as seen in the USA. Reports of damage to forests in the UK have, hitherto, been lacking. However, there are now unconfirmed reports that some symptoms of forest dieback in the UK and in Scandinavia bear comparison! It is relevant, in this context, that W German emissions of NO_x have increased by 77 per cent in the period 1965–80. The implications of these observations for proposed EC pollutant abatement directives are significant.

10.15. The direct effects of wet deposition appear to be insignificant at ambient concentrations. Virtually all experiments to date have been conducted in the laboratory with acid rain of unrealistically elevated acidity. There is no immediate evidence of direct damage to vegetation although studies of leaf surfaces of conifers indicate that acid rain along with acid gases and particulates, accelerates erosion of the wax layer of conifer needles. However, some pointers to long term effects of acid deposition have emerged from Manchester University where work on raised bogs indicates a persistent adverse effect on the growth of mosses on the Peninnes down wind of the Manchester connurbation compared with mosses from bogs in other areas of the UK. There appears also to be a persistent inhibition of microbial enzyme activity in the Peninne systems. This is the only real indication of direct effects of wet acid deposition in terrestrial systems. The work suggests that a long term perspective is needed in assessing such impacts given that these areas of the Peninnes have been exposed to acid deposition for well over a hundred years, the last decades of which have seen a continuing decline in pollution, at least in terms of dry deposition of SO_2.

10.16. *Soils, Bedrock and Hydrology.* The theoretical consequences of acid deposition upon soils and thus upon plant life, are well known. Increased acidification may result in the inhibition of microbial processes including decomposition and nitrogen cycling, the leaching of calcium and the inhibition of mycorrhizal development essential to the establishment and growth of trees and other plants. There is evidence from Scandinavia which suggests that these and other soil properties may be affected. Nonetheless, the ability of the affected soils to "carry" vegetation is unknown. There is a strong case to monitor the properties of selected soil types in areas at risk from acid deposition. Practical evaluation is complicated because of variations in geological strata and soil type across the UK, by current land use and management practices, and by gaps in our knowledge of the fundamental processes of geochemical cycling. Furthermore, the main emphasis of research, hitherto, has focused on the pathways of acid deposition into soils and their outputs and effects upon aquatic systems. These issues are discussed below.

10.17. The stages of transfer of acid deposition to soils and vegetation, and then to surface and groundwaters are complex. Much depends upon the contact time and rates of reaction that occur in the solid matrix of the soil. A number of studies at the Macaulay Institute, Aberdeen University, Nottingham University and elsewhere seek to understand these processes. For instance, the ITE in collaboration with the Institute of Hydrology (IH), BGS and the University College of North Wales, is examining the natural variation of acid inputs to soils and their consequences for the weathering of rocks. The work includes studies of the basic processes of geochemical cycling in improved and unimproved grassland catchments in Plynlimon and a range of satellite catchments in the Lake Districts. Parallel work on afforested catchments by ITE and IH in collaboration with the Forestry Commission (FC) in Wales and Scotland with specific reference to the quality and quantity of output waters in catchments under different management regimes, is also in progress. This work links closely with other studies of rivers and catchments designed to ascertain impacts upon the quality and life of freshwaters (para 11.7).

10.8. Studies in the west central Highlands of Scotland indicated that streams draining catchments afforested for at least 25 years with conifers, were more acid than those draining unafforested catchments. Other studies by IH, ITE, FBA, etc, have reached similar conclusions with precise conditions depending upon the nature of the individual catchments. For instance, in Plynlimon much potassium is locked in afforested areas where the streams are colder, more turbid and contain less fish than in unafforested areas. The influence of episodes of rainfall upon flow rates is most marked in catchments with bare rock which generate pulses of high flow and high acidity, especially during periods of snow melt. It is important to emphasise that no one catchment is typical of the UK, there being an infinite variation in soil and bedrock type, altitude and exposure, afforestation, management practices, rainfall and other characteristics. Some understanding of the basic characteristics of soils and their responses to acidification under different circumstances is thus critical to the evaluation of acid deposition and its effects.

10.19. New work at Aberdeen University(13) and elsewhere, sponsored by DOE and NERC, has this objective in mind, and seeks to answer six important questions, namely:

i. to what extent does acid pollution accelerate the deterioration of soils;

ii. how does acid deposition influence the mobilisation and transport in soils of aluminium which may be toxic to plants;

iii. how does acid pollution accelerate the occurrence of water element deficiencies in animals and plants;

iv. how does vegetation type and land use change influence acidification and soil processes;

v. how important are brief, episodic events in relation to long term exposures to acid deposition;

vi. how significant is the concentration effect of evaporation of water from precipitation in terms of the eventual quantities of rainfall which reach the forest floor?

10.20. It appears that, except in grossly polluted areas, the acceleration of weathering is relatively insignificant but grows in importance on thin soils, and in soils which are naturally acidic. The buffering effect of stored water in thicker soils is especially important because it reduces both the volume and the acidity of early flushes from storms and snow melts.

10.21. Aluminium tends to be mobilised at high concentrations in acid soils only during storm events, the actual amount of free aluminium depending upon the concentration and the complexing properties of the dissolved organic matter in pure waters. Acid precipitation appears, through repeated leaching, to increase dissolved concentrations of iron and aluminium by microbial activity. The processes involved are under investigation. The processes of acidification may also enhance leaching of cobalt, zinc, copper, manganese and other elements resulting in a variety of deficiencies, and alter supplies of available nitrogen and sulphur to plants. Information of temporal changes in the concentrations of solutes and in acidity in precipitation, especially during the early stages of episodes (eg storms) are vital to this and other work discussed in this paper.

10.22. *Surface and Ground Waters.* The implications of acid deposition for water supply from surface and groundwaters deserve consideration. The interest is focused primarily on the processes which might influence quality parameters in terms of human health, plumbosolvency, liming treatment, etc. Certain questions must be asked:

i. is there a need to provide a synoptic picture of the present status of UK surface and groundwaters—there are gaps in the existing data base;

ii. is the distribution of acidity in soil, ground and surface waters at a steady state or changing with recent and/or geological time;

iii. what is the precise, natural buffering capacity of soils and bedrocks along hydraulically active pathways;

iv. what is the role of acid deposition relative to other processes (eg geochemical, biological) in controlling water chemistry and what is the threat of acidification to water supplies;

v. what are the likely mobilities of trace elements other than aluminium, sulphur and calcium, as pH falls especially in relation to groundwater quality?

10.23. These issues have been barely touched hitherto but a number of new and proposed projects (involving IH and BGS) are designed to provide answers.(14) BGS is also seeking to define the precise natures of (a) the natural input of sulphur by mineralisation into soils in areas at risk from acidification, and (b) the extent to which such inputs are modified by acid deposition. Proposals to extend collaborative work in this field, notably between BGS and ITE, are in hand.

EFECTS IN SURFACE WATERS

11.1. *General Considerations.* The preceding section discusses processes in soils and rocks which may influence the quality and therefore the biota of surface waters. The importance of catchment studies is also stressed; those mentioned being reinforced by projects designed specifically to relate changes in acidity and other parameters of water quality to the range and quality of biota in affected areas. Such projects are sponsored by many bodies including the DOE, EC, NERC, CERL, the Nature Conservancy Council (NCC), FC, WRC, and the Welsh and Scottish Offices. They include new projects at FBA, ITE and universities in England, Scotland and Wales funded primarily by the NERC, the

DOE and the EC. Several involve direct collaboration between interested parties studying problems of acidification in specific, local catchments. Other projects are concerned with the detailed physical, chemical and biological processes of acidification, and with their physiological and ecological effects upon biota in streams, rivers and lakes. For instance, the FBA is investigating the chemistry of iron and manganese, and the interactions of these metals with particulates in acid waters. However, much of this work is new and will not contribute significantly to our knowledge for some time.

11.2. *Evidence of Acidification.* Data from the FBA (15), indicate that there has been no significant increase in the acidity of precipitation in Cumbria over the past 25 years, and that no tarn or lake has suffered from increased acidity within the past 50 years. However, there are reports of declining freshwater fisheries from the parts of the UK in areas which receive relatively large amounts of wet deposited acidity and which overlie slowly weathering bedrocks. Available estate records in Scotland are now being examined critically for fisheries data.

11.3. Except in one or two exceptional circumstances (eg in Cumbria), it is not possible to relate changes in fish populations to changes in water quality over long periods of time. Most monitoring systems devised by the Regional Water Authorities (RWAs) and their predecessors are, for a number of reasons, unsuitable and inadequate for the purposes of research into acidification problems. For instance, there are seasonal variations in the acidity of lakes and rivers(15) which may not be detected. The relevant headwaters and fish breeding grounds, areas which may well suffer most from storm and snow melt events, are seldom monitored. In addition, the FBA is concerned also about the lack of suitable technology to measure pH accurately in waters of low ionic strength. These issues are being investigated by the DOE Review Group on Acid Waters, but it would appear that the UK may require an intensive programme to define and measure changes in the freshwater environment, and the relation between such changes and the biology of aquatic organisms.

11.4. It would be instructive also to study the historical record of water quality in lakes and in groundwaters. Some work at University College, London has shown that the diatom record of four Scottish lochs remained unchanged from 1300 to 1850. Thereafter, there was a change in the record in favour of diatoms characteristic of acid waters. The Cumbrian record appears to differ, reflecting more varied changes over the centuries. Comparative studies of other standing waters in the UK, Scandinavia and other parts of Europe would be useful. The possibility of comparing sediment records with trace element and isotope profiles in groundwaters should also be investigated.

11.5. *Land use.* Unlike parts of Scandinavia and North America where changes in aquatic biota appear to be associated mainly with the distribution of acid deposition, the areas of Britain which are at risk, are subject also to major changes in land use and land management, notably the conversion of grass and moorlands to plantation forests. We have indicated already that afforestation results generally in the acidification of the environment. These changes have been reported for many plantations on soils overlying slowly weathering bedrocks. They include alterations to flow rates, increased turbidity, reduced temperatures and higher acidities in stream waters.

11.6. *Effects on Biota.* The consequences of changes in the environment for biota are reflected in alterations in invertebrate and in fish populations. In the more acid streams, many animal species are missing and fish populations may be absent or represented only by a few immigrants from more hospitable waters.

11.7. The effects of acid rain and of acidification generally have been considered largely in terms of H^+ ion concentrations, although good work has also been done at Lancaster University and elsewhere on physiology of fish in relation to pH and calcium metabolism. Whilst it is clear that salmon and trout, especially in their juvenile phases, are sensitive to acidity in natural waters, the precise mechanism of toxicity remains far from clear.(15) Increased in calcium concentration, however, may be just as important for the survival of fish as are reductions in acidity. FBA, ITE, universities and other bodies are developing new work in this field, some of which is focused on the ecotoxicology of soluble aluminium and other metals in acid waters. This work will need to take into account the relative impacts of prolonged *versus* episodic exposure to elevated concentrations of such elements. Work needs to be done on amphibia, including the ubiquitous frog, and on macrophytes, to complement the already existing investment in research on fish, invertebrates and diatoms.

11.8. The complexity of acidification processes is such that absolute proof of causality in terms of acid deposition affecting biota, is never likely to be obtained. This being so, the association between atmospheric pollution and uncontrolled land use changes as contributors to acidification in general at least needs to be resolved if only to indicate possible options for environmental control and for amelioration of impacts.

11.9. *Amelioration.* It has been suggested that the acidification of freshwaters might be minimised by the direct application of lime. Experiments on the direct application of lime to rivers and lakes in the UK and elsewhere indicate that the beneficial effects may be of limited duration. The restoration of the agricultural lime subsidy or its equivalent in upland areas might be more beneficial in the longer term. Systematic liming of catchments including strip liming of forests is under investigation in the UK.

11.10. Forestry presents somewhat different questions. Which species have the most acidifying effects upon the environment? Could broadleaves be planted as protective strips between conifer stands and water courses? Would it be more practicable to leave strips of land unplanted along the banks of streams and rivers? What other environmental factors (eg, wildlife, amenity) need to be considered? Which are essential to the development of control policies and improved land management practices? Some programmes of research by the NCC, the FC, the NERC and other bodies are beginning to investigate these questions.

CONCLUSIONS

12.1. We have reviewed the main issues which concern the NERC in the broad field of acidification of the environment. The Council and its officers will be pleased to advise the Committee on specific issues in greater detail; expert witnesses can be recommended and further, more detailed submissions provided, if so required. A detailed list of relevant research projects (contracts, grants, studentships) can also be provided if required but the Committee is advised that this list is likely to be almost as lengthy as the evidence itself, and that it is constantly expanding. For instance, new projects have reached the final stages of negotiation during the drafting of this text, and will add about £100k to the NERC programme for 1984–85, thus achieving a near equal balance of Science Budget and commissioned support.

12.2. Many of the new NERC projects are designed to answer fundamental questions about the chemical, physical and biological processes of acidification in the natural environment. However, the existing—if inadequate—information available suggests to us that there are significant, natural sources of atmospheric sulphur and nitrogen to be found in the oceans, soils and bedrocks. Work on oceanic sources requires international collaboration and the results may well have implications for international measures to control emissions and transfrontier pollution.

12.3. It is clear that acid rain is only one of many factors involved in environmental acidification. Land use, notably by forestry, is another potent factor in terms of soil structure and fertility, of water quality and of damage to fisheries and other freshwater organisms. Reports of damage to forests, however, may well involve exposure to other forms of atmospheric pollution, especially ozone.

12.4. It is clear that the control of environmental acidification in the longer term will need to consider measures and options other than reductions in emissions of sulphur dioxide. Measures to control oxides of nitrogen and the precursors of ozone pollution will probably be required. It is likely also that the use and the management of land will need to be organised in ways which minimise impacts upon surface and groundwater systems in certain areas of the UK. Further study of the advantages of liming land in acidified catchments is required. However, the practical problems of introducing such measures on a national scale require discussion with the relevant Departments (eg, MAFF, DAFS). We are less certain about the benefits of treating surface waters (eg, by direct liming) to ameliorate acidification problems; such measures may be cost-effective only in special circumstances.

12.5. Whilst it is possible to indicate some possible options for controlling acidification, we are not yet in a position to recommend on scientific grounds, the optimal mix of measures to adopt. Undoubtedly, some questions (eg, optimal emission control technologies) are outwith the competence and the responsibility of the Council to answer, as are the political and economic issues involved. However, we are in a somewhat better position to advise on the environmental implications of abatement control strategies and policies which may be preferred on technical and economic grounds, although we need to know more about the ways in which terrestrial and freshwater systems will respond to reductions in emissions of various pollutants. Some changes (eg, podzolisation of soils) may be almost irreversible. Others may be reversible in whole or in part over periods of time ranging from a few months to many years. Generally, we believe that acidification as a result of Man's activities is a serious problem which must be tackled effectively if we are to prevent serious and possibly permanent damage to the environment in the longer term.

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May 1984

Table 1. List of Principal Contributors to Evidence on Acid Rain Submitted by the NERC to the House of Commons Environment Committee

Institution	*Name*
NERC Institute of Terrestrial Ecology (ITE) (Director: Mr J N R Jeffers)	Professor F T Last Dr N Cape Dr D Fowler Dr M Hornung Dr P S Maitland Mr I A Nicholson Dr M H Unsworth
Freshwater Biological Association (FBA) (Director: Dr R T Clarke)	Dr D J Kinsman Dr W Davison Dr D W Sutcliffe Dr E Tipping
NERC Institute of Hydrology (IH) (Director: Dr J S McCulloch)	Dr P Whitehead Dr N Bevan Dr E Morris
NERC British Geological Survey (BGS) (Director: Dr G M Brown, FRS)	Dr M Edmunds Mr P J Moore Mr J Hull Dr D Peachey Dr J Plant Dr N Spiro
University of Aberdeen, Department of Soil Science	Professor J W Parsons Dr M Cresser Dr K Killman
University of Lancaster, Department of Biological Sciences	Professor T A Mansfield Dr P Freer-Smith Dr A R Wellburn

Table 2. Principal Investigators of other NERC Research

Institution	*Name*
University of Manchester	Dr J A Lee
Imperial College, University of London	Dr J N B Bell Dr M Ashmore
Marine Biological Association (MBA) (Director: Professor E Denton, FRS)	Professor E Denton, FRS
NERC Unit of Comparative Plant Ecology (UCPE) (Director: Professor I H Rorison)	Professor I H Rorison Professor P G Grime
University of Nottingham	Professor J L Monteith, FRS Dr D Crawford Dr J Colls
University of Loughborough	Dr V Black
NERC British Antarctic Survey (BAS) (Director: Dr R M Laws, CBE, FRS)	Dr R M Laws, CBE, FRS

Table 3. Other Organisations with relevant research referred to herein

Atomic Energy Research Establishment (AERE)
University of Manchester Institute of Science and Technology (UMIST)
University of Wales Institute of Science and Technology (UWIST)
Warren Spring Laboratory (WSL)
Water Research Centre (WRC)
Agricultural and Food Research Council (AFRC)
European Communities (EC)
Commission of the European Communities (CEC)
Department of the Environment (DOE)
Ministry of Agriculture, Fisheries and Food (MAFF)
Forestry Commission (FC)
Department of Agriculture and Fisheries for Scotland (DAFS)
Central Electricity Research Laboratories (CERL)
Meteorological Office (Met O)
Scottish (SDD) and Welsh (WO) Offices
Nature Conservancy Council (NCC)
Macaulay Institute for Soil Research
Regional Water Authorities (RWAs)
  Welsh (WWA)
  North West (NWWA)
Rothamsted Research Station
Grassland Research Institute (GRI)
Local Authorities (LAs)
US Environmental Protection Agency (EPA)

Appendix I to Memorandum submitted by the NERC to the House of Commons—The Environment Committee: Acid Rain

ORGANISATION OF THE NATURAL ENVIRONMENT RESEARCH COUNCIL

1. *The Council and its Committees*

1.1. The Chairman and Accounting Officer of the Council is currently Sir Hermann Bondi, FRS. The senior, permanent officer of Council is its Secretary—Dr J C Bowman. The Secretary of State for Education and Science (DES) also appoints the Council of members (currently 19) drawn from the universities, industry, state authorities, and the Chief Scientists of the Departments of Industry (DOI), Energy (DEn) and Environment (DOE), and the Ministry of Agriculture, Fisheries and Food, (MAFF). Assessors are nominated by the other Research Councils, the Royal Society, the University Grants Committee (UGC) and the Foreign and Commonwealth Office (FCO).

1.2. The Council has four Preparatory Groups (A-Earth Sciences; B-Terrestrial and Freshwater Life Sciences; C-Marine Life Sciences; D-Oceanography, Hydrology and Atmospheric Sciences), and the University Affairs Committee (UAC) which are true sub-committees of Council, each consisting of about six Council members plus assessors, advisors and the Chairmen of the relevant NERC University Grants Committees. They investigate policy issues in detail within their respective fields and may invite experts to attend their meetings and/or establish special *ad hoc* working parties, etcetera to provide Council with the best possible advice.

1.3. Acid Rain research falls mainly within the purviews of Preparatory Group B and Preparatory Group D between which there is considerable common membership. Preparatory Group B, is served by advisors from all the relevant NERC institutes and grant-aided laboratories including the Directors of the NERC Institute of Terrestrial Ecology (ITE), the Freshwater Biological Association (FBA), the British Antarctic Survey (BAS), and the NERC Unit of Comparative Plant Ecology (UCPE); by assessors from the DOE, MAFF, Forestry Commission (FC), Nature Conservancy Council (NCC) and the Department of Agriculture and Fisheries for Scotland (DAFS); and by the Chairmen of the NERC University Grants Committees for the Terrestrial (TLS) and Aquatic (ALS) Life Sciences. Similar arrangements apply to Preparatory Group D which involves notably the Director of the NERC Institute of Hydrology (IH) and the Chairman of the NERC Aquatic and Atmospheric Physical Sciences Grants Committee (AAPS).

1.4. The Grants Committees make their grant and studentship awards from the annual allocations of the Science Budget according to scientific and training merit, having due regard for the proper functioning of the dual-support system with the UGC. They may refer grant applications which present funding or policy problems, to the UAC to consider for support from its contingency reserve. The Council is also able to initiate new programmes of research through its Special Topic system on the advice of Preparatory Groups. Special Topic Programmes are characterised usually by interdisciplinary work and by collaboration between institutes, universities and other bodies in areas afforded high priority for research by the Council. Current examples relevant to acid rain include research in geochemical cycling, atmospheric processes and remote sensing. The Council also provides special services for research, such as remote sensing and image processing facilities, and stable isotope analytical services (1).

2. *Funding of NERC Research and Postgraduate Training*

2.1. The Council's expenditure in 1982–83 was £84.14m, of which £58.04m was the Parliamentary Grant-in-Aid ("Science Budget") allocated by the Department of Education and Science (DES) on the advice of the Advisory Board for the Research Councils (ABRC) (1). The remainder was composed of commissions for NERC research received from numerous customers, the main ones being the DEn (£9.47m), the DOE (£5.81m), the DTI (£2.69m), the Overseas Development Administration (ODA) (£2.86m), the MAFF (£2.02m), the European Communities (EC) (£0.71m) and the NCC (£0.27m). The balance of commissions (£2.45m) was received from an increasing range of customers including local authorities, industry, private consultants and international agencies. The estimated income for 1983–84 and 1984–85 includes some substantial increases in support from the DOE, the EC and the Science Budget for research on acid rain and on acidification processes in the natural environment (Section 6).

2.2. The readily identifiable expenditure of NERC Science Budget funds in support of universities and polytechnics was £14.86m in 1982–83 of which the Grants Committees and Council disposed of £9.61m on research grants, studentships and training awards, the remainder being spent on special services for universities such as research vessels. Approximately £43.18m or 74 per cent of the Science Budget was used by the Council to support fundamental and strategic research and relevant services under its direct control including support of postgraduate students in NERC institutes and grant-aided laboratories[1] which also undertook more applied research commissioned by customers including work for which the Council acted as an agency or main contractor (notably for DEn) and subcontracted work to industry, universities and other organisations.

2.3. The Council operates a strict system of contracting commissioned work on a project-by-project basis, each project being costed and cleared by headquarters acting for the institutes and grant-aided laboratories and, where appropriate, for subcontractors in industry, universities, etcetera. Formal liaison and reporting on each project is handled by the nominated officers of the customer and contractor. In some cases, it is possible to create consortia of interests for the funding, direction and conduct of work involving several customers and/or NERC establishments. Frequent and informal contact is encouraged by the Council between nominated officers and scientists at the working level, and between senior officers of the NERC and its customers. These contacts are reinforced by the scientific and review groups on which the NERC is represented, either as a full member or as an assessor. In addition, representatives of customers sit on NERC committees and may attend the scientific meetings of NERC Coordinating Groups and other *ad hoc* committees which discuss progress of research in detail (Appendix II).

2.4. Such contacts facilitate dialogue on existing problems, priorities and results in research, and on ideas for new work. The most difficult problem facing the Council in all of these forums, is to determine priorities and programmes for strategic research—the middle ground between fundamental studies and applied R & D—and to persuade customers of the merits of such work for commissioned support. Where such support is not forthcoming, the Council may deploy Science Budget resources to initiate pilot work and/or to maintain a minimum of effort with a view to securing customer support in the longer term. This ability is important in cases (eg NERC research on aspects of acid rain) where customers' priorities change, causing them to withdraw their support, only to return their custom at a later date. It is important also for the Council to maintain a core of work which is independent of industrial and departmental policy objectives, and which provides a scientific basis for the independent assessment of environmental impacts and control options.

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[1] Footnote: The locations of NERC institutes, units and grant-aided laboratories may be found in the Council's Annual Report for 1982–83.[(1)]

Appendix II to Memorandum Submitted by the NERC to the House of Commons—The Environment Committee: Acid Rain

COORDINATION WITH OTHER BODIES IN ACID RAIN RESEARCH

1.1. Monitoring and research on acid deposition is well served by a network of policy and advisory committees organised by the DOE (eg air pollution monitoring management group; research requirements committees; water advisory committees) and which the NERC attends either as a full member, by invitation or as an assessor. The NERC is involved in relevant activities of professional bodies such as the Royal Society(8) and the British Ecological Society. Scientists sponsored by the NERC in institutes, grant-aided bodies and universities also serve on the various acid deposition review groups being established by the DOE (eg,(9)).

1.2. At the operational level, the Council sponsors two groups designed to promote the exchange of information, collaboration in research and the initiation of new research proposals, *viz.* the long-established Liaison Committee on Air Pollution Effects Research (CAPER) and the new Coordinating Committee for Research in Atmospheric Chemistry (CCRAC). There are close links also with the parallel Group for Research on Acid Waters (GRAWS), sponsored by the Central Electricity Research Laboratories (CERL). CCRAC and CAPER both involve active scientists from institutes, grant-aided laboratories and universities sponsored by the NERC, together with appropriate representatives of other interested parties such as the DOE, MAFF, the Atomic Energy Research Establishment (AERE), CERL, the Meteorological Office (Met O), Warren Spring Laboratory (WSL), and overseas research groups. The CAPER has recently established a formal link with a parallel group of scientists in Scandinavia. The Council has also formed an *ad hoc* group of prime mover scientists to coordinate research on acid precipitation in its various institutes, including ITE, FBA, IH, and BGS.

1.3. There is extensive and pervasive collaboration at the working level between scientists in various institutions. Examples include NERC work in the AERE and universities on atmospheric processes; in ITE and universities on a range of problems including deposition processes, pathways of pollutants in terrestrial systems, and their effects on plants and soils; in ITE, WSL, AERE, Met O, CERL, the Macaulay Institute and other bodies on the monitoring and measurement of acid deposition(9); in FBA and universities on the measurement pH and chemical processes in surface waters; in ITE, IH, FC, BGS, FBA, the Welsh Office, the Scottish Office and universities on geochemical processes associated with acidification in forests and upland streams; and in IH, FC, regional water authorities (RWAs) and universities on various aspects of catchment processes. Such collaboration is an essential prerequisite for successful research into questions which require detailed, painstaking and long term work in the field. The instrumentation and facilities used in such work are usually expensive, and their use generates heavy demands for analytical (eg chemical, stable isotope) and data processing services.

1.4. We refer in Appendix I to the Council's system of commissioned research and its contacts with customers. There is close and frequent contact between senior officers of the NERC, the DOE, and the Commission of the European Communities (CEC) at project and programme levels. Scientists sponsored by the NERC play important roles on DOE and EC advisory committees concerned with acid deposition research. In the terrestrial sector, the NERC—through the ITE—acts as coordinator for the DOE and as UK lead institution for the CEC for major programmes of commissioned research in institutes and universities.

ACID RAIN RESEARCH AT THE MACAULAY INSTITUTE FOR SOIL RESEARCH, ABERDEEN

H G Miller

RANGE OF STUDIES COVERED

Interest in acid rain at the Macaulay Institute grew from earlier work on both nutrient cycling in forest ecosystems (Department of Peat and Forest Soils) and acidity in cultivated soils (Department of Soil Fertility).

In 1976 an existing study of nutrient cycling in stands of Sitka spruce was expanded to include a new objective "to assess the input and retention of elements from the atmosphere, including anthropogenic pollutants (SO_2 and NO_x), and provide information to assess the ecological and pedological significance of these processes". Rainwater collection, above and below the forest canopy, at these experiments continued until 1981. A further, and specifically acid rain, investigation was then started in 1979 at Glen Tanar, on Deeside, with financial support from the Central Electricity Generating Board. Here changes in rainwater chemistry were monitored as water passed through stands of different tree species. The investigation was completed in early 1983 and has been followed, at an adjacent site, by an ARC Research Studentship look at the factors controlling atmospheric inputs to different vegetation types. Also in 1983, two major new investigations were started that include in their objectives study of acid rain effects. The first, at Balquhidder, is a collaborative project with the Forestry Commission and the Institute of Hydrology to relate atmospheric inputs to streamwater quality in forested and unforested catchments. The second, at various sites, is part of a wider EEC-funded investigation into the factors controlling the availability of nitrogen on very poor soils. In this study a range of pollution inputs has been ensured by including sites in the west and south of Ireland, in addition to those being studied in eastern Scotland.

Finally, a new and ambitious project is being started with finance from the Department of the Environment, finance that will enable four research staff to be employed for periods from three to five years. The objective is to elucidate those factors that lead to loss of acidity into streams, and the role, if any, played by trees. The work will be under the general direction of Professor H G Miller and Dr B W Bache and will be aligned closely to other investigations in the Department of Soil Science of the University of Aberdeen and in DAFS Freshwater Fisheries Laboratory, Pitlochry.

FLUX OF ACIDITY THROUGH SPRUCE STANDS

The element cycling study, of which this was part, centred on experiments located at six stands of similar aged Sitka spruce at sites chosen to cover the range of Bioclimatic regions in which this species is planted. This automatically ensured considerable variation in pollution input between sites (Table 1). At all sites there was a reduction in acidity as rainwater passed over the tree foliage. This was more than matched by the amounts of base cations gained by the rain through crown leaching, the equivalents of such cations gained being two to eight times greater than the equivalents of hydrogen ions lost.

The long-term means in Table 1 hide considerable annual variation. Time series analysis showed that at no site was there any annual variation in the pH of input water, or of water collected in funnels surmounted by a vertical cylinder of polyethylene-coated wire mesh designed to intercept aerosols and fog droplets from the atmosphere (filter gauge). At the more polluted eastern sites, however, a pronounced annual variation developed in the acidity of both throughfall and stemflow. This is exemplified by the comparison in (Figure 1) between Leanachan, from the west coast, and Fetteresso, from the east coast. The regular variation in streamwater pH at the latter site reflects variations in stream flow from summer to winter.

Table 1 Changes in amounts of hydrogen ion as rainwater passes through the canopy of Sitka spruce at Fetteresso (F), Leanachan (L), Elibank (E), Strathyre (S), Kershope (Ks) and Kilmichael (Kl) measured over five year periods

	Forest					
	F	L	E	S	Ks	Kl
Years of collection, April–April	1973–78	1973–78	1974–79	1974–79	1975–80	1976–81
Mean pH of incident rain	4.13	4.54	4.10	4.46	4.20	4.30
Equivalents $H^+ ha^{-1} yr^{-1}$:						
Incident rain	640	430	750	480	750	970
Throughfall	380	80	200	220	380	130
Stemflow	150	60	70	170	210	220
% change in H^+ beneath trees	−17	−67	−64	−19	−21	−64

The large amount of data collected in this project is still being processed.

EFFECT OF TREE SPECIES ON FLUX OF ACIDITY

At Glen Tanar, on Deeside, bulk precipitation, filter, throughfall and stemflow gauges, together with water collectors beneath the ground vegetation, below the humus layer and in the mineral soil, were installed in and around stands of birch (predominantly *Betula pendula* Roth.), larch (*Larix kaempferi* (Lamb.) Carr.), young (aged 45 years) and old (aged 110 years), Scots pine (*Pinus sylvestris* L.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and heather (*Calluna vulgaris* L.) heathland. The intention behind this choice of stands was to facilitate discussion of the likely effects of proposed or past changes in land use, including conversion to intensive plantation forestry of open heathland, or of old open-grown coniferous forests, or of natural broadleaved woodlands. Marked differences were found between vegetation types, and even between the two ages of Scots pine, in the acidity of water draining through different layers (Table 2). A striking feature is that even at depth in the mineral soils these differences persist, with greatest acidity being found beheath the old Scots pine that was chosen as a surrogate of pre-twentieth-century Scandinavian forests.

Table 2. Mean pH of water at various points in different ecosystems for the year November 1980 to November 1981 at Glen Tanar in north-east Scotland

pH of bulk precipitation 4.6
pH of filter gauge water 4.4

	Vegetation cover					
		Pinus sylvevestris				
Water flux	*Calluna vulgaris*	old	young	*Picea sitchensis*	*Larix kaempferi*	*Betula* spp.
Throughfall	—	3.9	4.7	5.4	4.8	4.8
Stemflow	—	3.1	3.5	3.9	3.7	3.9
Beneath ground vegetation	4.5	5.5	5.5	*	4.7	6.4
Beneath humus	4.0	3.6	3.8	4.4	4.6	5.1
Below rooting zone	5.6	4.4	4.7	5.5	4.9	6.6

* No ground vegetation grew beneath the *Picea sitchensis*

Despite the low pH values in the deeper mineral soils the stream that drained the area in which these stands were located remained almost consistently neutral, with the notable exception of November 1981 (Figure 2). At this time high inputs of H^+ and SO_4^{2-} in heavy rain were reflected by an "acid episode" in the stream. This acidity was also noted in water from zero tension lysimeters installed in the soil but not in water collected in tension lysimeters (porous cup samplers in which a negative pressure is maintained). More evidence is required, but these observations seem to support the hypothesis that for acidity to reach a stream conditions must be such that water drains very rapidly through or over the soil. Certainly any sample that includes capillary water (tension lysimeters) will indicate greater neutralisation than is occurring in channeled drainage water (zero tension lysimeters).

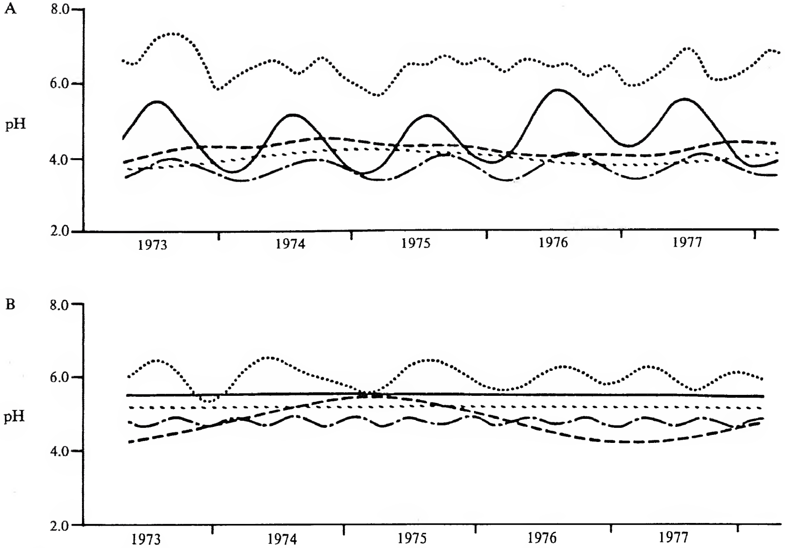

Figure 1.
Variations (A) at Fetteresso forest, on the Scottish east coast, and (B) at Leanachan forest, on the relatively unpolluted west coast, in pH of bulk depositition (— — — —), water collected in the "filter guages" (- - - - - -), throughfall (————), stemflow (—·——·) and streamwater (............) measured over the five years 1973-78 in crops of Sitka spruce.

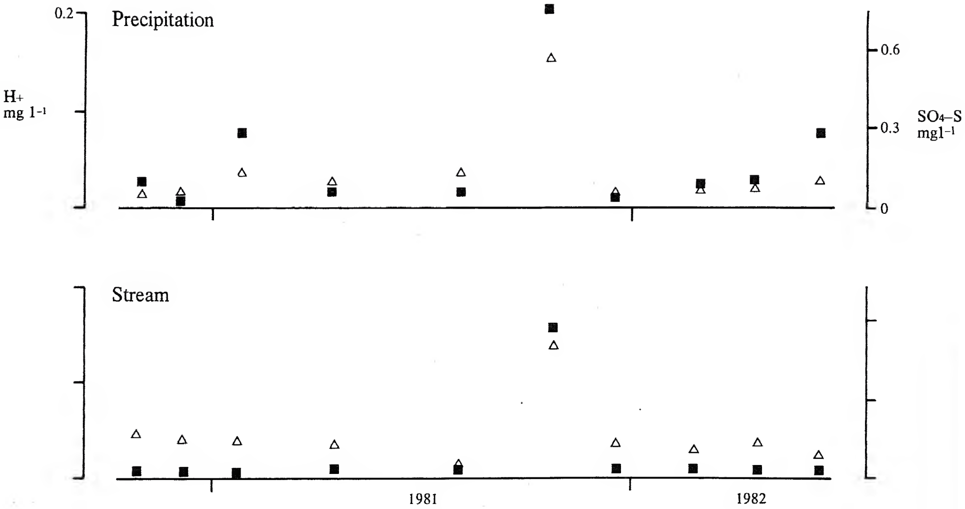

Figure 2.
Concentrations of hydrogen (■) and sulphate sulphur (△) measured in samples collected at the birch stand in Glen Tanar.

[Continued

(tension lysimeters) will indicate greater neutralisation than is occurring in channeled drainage water (zero tension lysimeters).

CATCHMENT STUDY

The recent installation, by a consortium including the Forestry Commission and the Institute of Hydrology, of stream-flow monitoring equipment in two catchments (one forested and one not) at Balquihidder presented the ideal opportunity to quantify the rate of loss of base cations and acidity from two catchments under contrasting land use. Continuous sampling of the stream draining the forested catchment started in the summer of 1983, whilst that in the non-forested catchment started in the following autumn. In addition, bulk deposition, aerosol, throughfall and stemflow gauges have been installed at eight plots throughout the forested catchment (three in Sitka spruce, three in Norway spruce, and one each in pine and larch) so that accurate estimates can be made of the inputs from the atmosphere. The location is one that can be expected to receive acid inputs, being only a few kilometres away from the earlier Strathyre study (Table 1).

NITROGEN CYCLING AND ACID RAIN

The Macaulay Institute, together with the Forest and Wildlife Service of the Republic of Ireland, have recently been awarded EEC finance, under the CREST[2] programme, to investigate aspects of the factors controlling nitrogen availability in forests on poor soil. Included in the objectives is a study of the effects, if any, of acid precipitation on the nitrogen cycle. In Scotland the study is centred on existing field experiments near both Fort Augustus and Inverness, which together with a very similar experiment in County Cork provides an unusually wide-range of acid inputs. Certain parts of the study will also be duplicated at Balquihidder (see previous section) and in County Mayo, on the extreme west coast of Ireland.

The intention is to examine in detail the cycle of nitrogen, including microbial aspects, in replicated plots both of pure spruce and of spruce in mixture with larch or pine. At all sites the spruce has become extremely nitrogen deficient when planted pure, but not when planted in admixture. Comparison of results between plots within experiments, and between experiments, should give some indication of whether acid inputs are interfering with organic matter decomposition and mineralization of nitrogen.

FACTORS CONTROLLING ATMOSPHERIC INPUTS

In 1983 an ARC Research Studentship was obtained for a study with the objectives (1) to determine the magnitude of, and factors controlling, deposition of wet aerosol and dry particulate matter to vegetation and soil, and (2) to assess the ecological importance of this input of nutrients and pollutants in upland areas. It should be noted that gaseous inputs are specifically excluded, as these are already being investigated by Dr D Fowler and his colleagues at the Institute of Terrestrial Ecology.

The project is centred on a field site, again at Glen Tanar, where the input is being assessed in old and young Scots pine and heather at each of two locations separated by 100 m in elevation. This aspect of the work is already well under way and will be supplemented by detailed short-term studies, using different designs of aerosol collectors, comparing exposed and sheltered tree shoots etc, in order to determine the factors of the vegetation that influence collection of acidic, or neutralising, aerosols and fog.

NEW DOE-FINANCED STUDY

This is a major new investigation that is only at the stage of appointing the necessary staff. The proposal arose from the earlier experimental work by the Department of Peat and Forest Soils, as detailed above, in conjunction with expertise in soil acidity *per se* within the Department of Soil Fertility. The overall objective is to elucidate how acidity, both pollution-derived and natural, passes through upland ecosystems and into streams without being neutralised within the soil, and to establish the role, if any, of trees in this process. Such an understanding will help to resolve the relative importance of introduced, as against natural, acidity in the reported acidification of streams and to suggest possible means of managing the riparian zone to eliminate or minimise the effect.

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[2] CEC Research and Development Programme in the field of raw materials; Sub-Programme on "Wood as a Raw Material".

The study is comprised of four distinct but inter-related parts:

(i) At post-doctoral level; an investigation into changes in rainwater chemistry as it passes through forests and into the mineral soil, attempting to explain the reactions at leaf surfaces, the significance of this for acid production in the rhizosphere (the base cations used to neutralise the rain must be soil-derived), the reasons for the observed seasonal variation in hydrogen ion exchange at polluted sites (Figure 1), the importance and source of stemflow acidity, the effect of ground vegetation and soil organic layers, and the observed differences between species and tree age (Table 2).

(ii) At post-graduate level; a study of the biochemical and physiological factors leading to hydrogen ion exchange and foliar leaching at leaf surfaces as a contribution to explaining the mechanisms in (i).

(iii) At post-doctoral level; an examination of the hydrology of water drainage in forested and non-forested areas in order to determine how, and under what circumstances, acidity fails to be neutralised within the soil, the size of the catchment for such acidity, the contribution of natural acidity, the importance of an introduced mobile anion and the possibility of manipulating drainage pathways to ensure full neutralisation.

(iv) At post-graduate level; an investigation of exchange characteristics of soils necessary to explain aspects investigated under (iii).

Site selection for this study is to start in March and the project is estimated to last until 1988.

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EVIDENCE SUBMITTED BY THE INSTITUTE OF TERRESTRIAL ECOLOGY

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SUMMARY

1. Since the Institute's programme of atmospheric pollution research was started in 1974, its annual commitment has increased to about 14 man-years.

2. The Institute's research has been funded by (i) the Natural Environment Research Council, through its subvention from the Department of Education and Science, (ii) the Department of the Environment and (iii) the European Community.

3. Members of the Institute have maintained close liaison with the British Geological Survey, the Forestry Commission, the Institute of Hydrology, Warren Spring Laboratory, the Universities of Aberdeen, Lancaster, London and Nottingham and the University College of North Wales.

4. Most of the Institute's early work was concentrated on the characterisation of the *pollution environment.* Pollutants rarely occur one at a time. Instead they usually occur in mixtures.

5. When fossil fuels are burnt, sulphur and nitrogen pollutants are emitted, or develop, including gaseous (sulphur dioxide, nitric oxide and nitrogen dioxide) and particulate (sulphuric and nitric acids and ammonium sulphate) forms.

6. The composition of the mixtures of gases, including ozone derived from oxides of nitrogen, is constantly changing, each gas having its own distinctive diurnal and seasonal patterns of change.

7. Members of the Institute have investigated the (dry) deposition of sulphur dioxide in dry weather but little is known of the factors governing the transfer of oxides of nitrogen and ozone from the atmosphere to plant and soil surfaces.

8. In contrast to that of gases, the transfer of particulate pollutants is inefficient in dry conditions. Instead, particulate pollutants are more efficiently removed by fog- and rain-drops, snowflakes and hailstones (wet deposition, acid rain *sensu stricto*).

9. Rain in the east of Scotland is more acidic than that in the north-west. On the other hand, because of the overriding effects of amounts of rain, the acidic inputs in the southern Uplands and west central Highlands of Scotland are larger than elsewhere in Scotland.

10. Apart from assessments of rain acidity in Scotland, knowledge of the pollution enviroment in rural Britain is extrapolated from observations made in urban locations. It is essential to establish a *national network* to *monitor the rural environment.*

11. Having contributed to the characterisation of the pollution environment, the Institute's programme has been increasingly diversified, to initiate studies of:

(a) the *quantitative effects* of the pollution environment on the *growth of annual* (cereals) and *perennial* (pasture grasses and trees) *plants*,

(b) the *effects of branches and foliage* of deciduous and evergreen, coniferous and broad-leaved trees on the *chemical composition of rain* percolating to soil,

(c) the *effects of acidic inputs* on (i) *soil processes*, including the weathering of bedrock, and (ii) the chemical *composition of drainage water* flowing into bodies of standing and running freshwater,

(d) the *effects of acidified drainage water* on the *chemistry* of standing and running *freshwaters* in catchments overlying different types of bedrock,

(e) the *ecotoxicology of aluminium* and other heavy metals which occur in enhanced concentrations in some acidic bodies of freshwater.

12. Results of the Institute's research are being shared with colleagues elsewhere in Britain and in Canada, the Federal Republic of Germany, Norway, Sweden, the USA etc.

1. INTRODUCTION

1.1. The Institute of Terrestrial Ecology (ITE) has contributed to the evidence being presented to the Select Committee by the Natural Environment Research Council. The present document should therefore be regarded as a supplement in which the activities of ITE, and the implications of these activities, are described in greater detail.

1.2. In the request received from the Clerk to the Committee, members of the Institute were asked to present *their* evidence relevant to the Committee's terms of reference:

1.2.1. To examine available evidence and current research on the emission, distribution and deposition of acidity in precipitation.

1.2.2. To examine the environmental effects of acid rain.

1.2.3. To examine the levels of, and mechanisms for, setting emission control standards in the light of evidence on the effects of acid rain.

1.2.4. To examine control emission technology, its cost, and any effect it would have in reducing any environmental damage attributable to acid rain.

1.3. In responding, the Institute recognizes that its responsibilities are restricted to the biology of terrestrial ecosystems and to a lesser extent aquatic ecosystems. This memorandum is, therefore, not concerned with the effects of 'acid rain' on human health, materials and visibility. Nor is it concerned with emission control technology—a subject also outside the competence of the Institute.

2. BACKGROUND

2.1. A wide range of atmospherically dispersed sulphur and nitrogen compounds, including the gaseous sulphur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), nitric acid (HNO_3) and ammonia (NH_3) and particulate ammonium sulphate ($(NH_4)_2SO_4$), ammonium bisulphate (NH_4HSO_4), sulphuric acid (H_2SO_4) and ammonium nitrate (NH_4NO_3) are transferred to vegetation and other surfaces, including soil, by 2 processes:

2.1.1. *dry deposition*—the direct and relatively efficient transfer of gases and the more restricted transfer of particles measuring 0.1–1.0 μm (diam.)—the size range in which most pollutant SO_4^{2-} and NO_3^- occur.

2.1.2. *wet deposition*—an indirect process whereby particulate pollutants, and some gases, are carried in solution or suspension in, or on, fog- and rain-drops, snowflakes or hailstones.

2.2. Formerly, acid rain was used only to refer to pollutants which were deposited by rain, snow or hail—wet deposition—but the term is now used popularly to include acidifying atmospheric gaseous pollutants removed by dry deposition.

2.3. Because the balance of wet to dry deposition markedly differs in different regions (urban contrasted with rural) and different countries (Sweden and Norway compared with Central Europe), it is essential to characterize the *pollution-environment* before considering the fate and effects of atmospheric pollutants.

3. RESEARCH ON THE EMISSION, DISTRIBUTION AND DEPOSITION OF ACIDITY IN PRECIPITATION

3.1. Despite the publication of *Air and Rain. The Beginnings of a Chemical Climatology* in London in 1872 by R A Smith, and its reference to acid rain, atmospheric pollution, except near to smelters and brickworks liberating heavy metals and fluorides, was, to all intents and purposes, conceived in terms of dust and SO_2 until the 1950s (vide Clean Air Act, 1956).

3.2. Recent observations made in many parts of the world, but with a strong contribution by the Institute of Terrestrial Ecology, have shown that the atmosphere contains a constantly changing mixture of gaseous pollutants, with most attention being paid to SO_2, the oxides of nitrogen (NO_x) and ozone.

3.3. ITE's research programme, started in 1974 and supported more or less continuously since 1975 by the Department of the Environment, with the later involvement of the European Community, has defined the pollution environment of a plantation of Scots pine (*Pinus sylvestris*) at Devilla in Central Scotland.

3.4. Daily concentrations of SO_2 at Devilla are predictably maximal at 10.00 GMT and minimal at 15.00–18.00 GMT. Amounts of SO_2 are often matched by similar mean concentrations of oxides of nitrogen whose peaks, and troughs, coincide with those of SO_2. In contrast, concentrations of ozone, with natural sources being augmented by ozone produced as a result of photochemical reactions involving NO_x and hydrocarbons, are maximal about 15.00 and minimal at 08.00 (Figure 1).

3.5. Seasonal mean concentrations of SO_2 and NO_x at Devilla were maximal in winter, whereas those of O_3 were largest during spring and early summer (Figure 2).

3.6. These generalisations about daily and seasonally changing concentrations of atmospheric pollutants are derived from data from one site. Much less is known about events elsewhere in Britain, and, for that matter, other parts of the World—a major gap that needs to be filled if the fates and effects of atmospheric pollutants are to be fully understood.

3.7. Our knowledge of the atmospheric concentrations of gaseous pollutants in rural Britain is largely inferred from emission data and/or records of atmospheric concentrations in urban areas. *It is now essential to establish an effective network to monitor the rural*

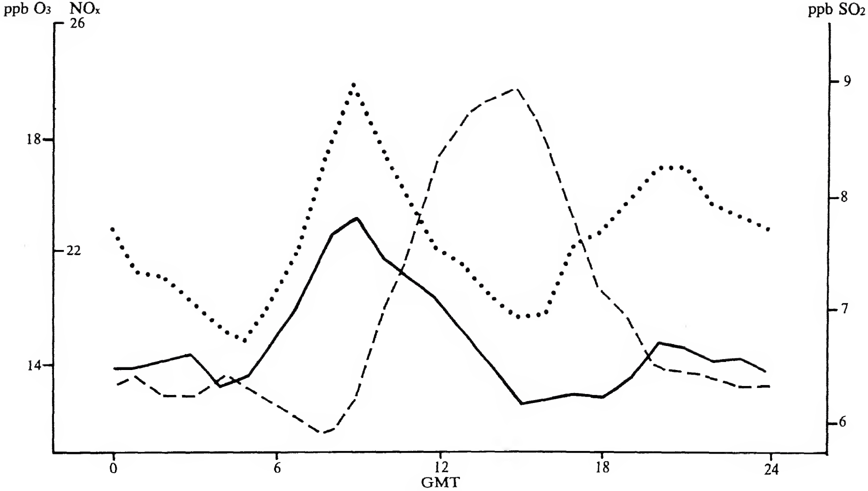

Figure 1.
Diurnal changes in concentrations (parts per billion, ppb) of sulphur dioxide (SO_2, ————), oxides of nitrogen (NO_x, ••••••••) and ozone (O_3, — — — —) in the atmosphere immediately above the canopy of a Scots pine plantation at Devilla, Central Scotland (Means for 1978) (Nicholson et al., 1980b).

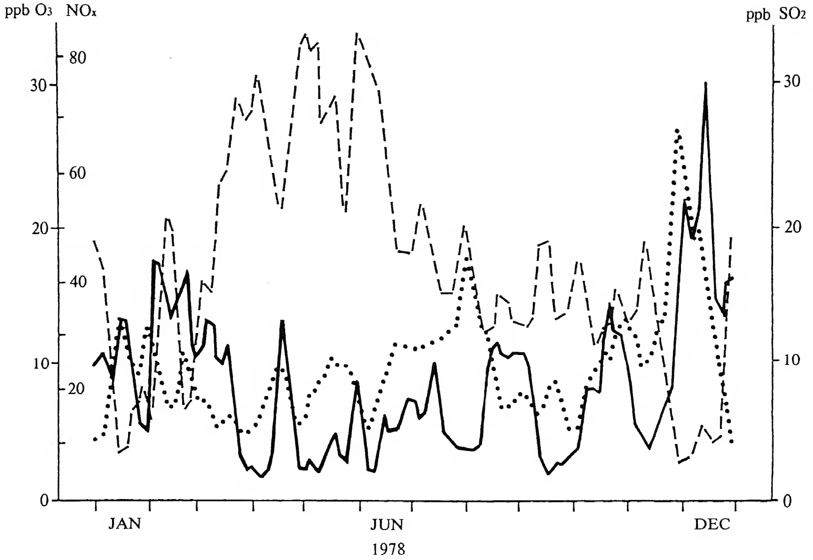

Figure 2.
Seasonal changes in concentrations (parts per billion, ppb) of sulphur dioxide (SO_2, ———), oxides of nitrogen (NO_x, ········) and ozone (O_3, — — — —) in the atmosphere immediately above the canopy of a Scots pine plantation at Devilla, Central Scotland (Means for 1978) (Nicholson et al., 1980b).

[Continued

environment, a network that should include SO_2, NO, NO_2 and ozone, the latter being thought to be strongly implicated in forest dieback in Germany.

3.8. Knowledge of the physical and chemical aspects of the transfer of SO_2, by dry deposition, has increased in the last few years. Work in Scandinavia has been paralleled within ITE by measurements of SO_2 dry deposition, using a fluxatron, for which it was necessary to incorporate a rapid response (flame photometric) sulphur detector. Most of the dry-deposited sulphur was attributed to SO_2; the use of a filter indicated that particles only accounted for seven per cent of the total load of airborne sulphur at Devilla. When using the sensor with, and without, a "scrubber", the ITE team were unable to find evidence of atmospheric hydrogen sulphide (H_2S). During dry weather, the deposition of SO_2 to the Scots pine canopy at Devilla was faster during day than at night (Figure 3); other observations indicate that night-time deposition is faster when surfaces are wet than when they are dry (Figure 3). However, the amounts of deposition may be restricted by the chemical composition of the water films.

3.9. Despite the improvement in our knowledge, much more remains to be known of the factors controlling the dry deposition of SO_2; we know very little about the dry deposition of oxides of nitrogen and ozone in the UK—these deficiencies should be made good.

3.10. Until the recent industrial recession intensified, the amounts of SO_2 emitted over the UK remained, despite the increasing use of natural gas, more or less the same as in 1956 but the proportion emitted at a relatively high altitude (as a result of the tall-stack policy principally applied to power generation) had significantly increased. This policy, together with other ameliorative measures, decreased ground-level concentrations of pollutants, specifically dust and SO_2, in urban areas, but increased the chances of gaseous SO_2 and NO_x being converted to particulate forms of sulphate (SO_4) and nitrate (NO_3) which together are the main contributors, in northern Britain and elsewhere, to the excess acidity of acid rain.

3.11. Even now our knowledge of the acidity of wet deposition, usually conceived in Britain in terms of rain, although mist and snow may be important in upland areas, is patchy. Early observations made at the University of Nottingham, and being further developed by ITE, AERE Harwell, and the Universities of Edinburgh and Manchester, show that wind-driven mist and cloud, often with larger concentrations of solutes than rain, are efficiently captured by trees, but inefficiently caught by rain gauges. Because of our dependence on rain gauges, the occurrence of acid deposition may have been underestimated.

3.12. For some years, ITE has managed a network of bulk rain collectors located from the Lake District of England in the south to the northern coast of mainland Scotland (Fowler *et al.* 1982*b*). The data, many of which were quoted in the 1983 Warren Spring Laboratory publication *Acid Deposition in the United Kingdom*, show that the mean acidity of rain was less in the northwest of Scotland (pH 4.7) than in the east of Scotland (pH 4.2) (Figure 4). This distribution contrasts with that of atmospheric SO_2, whose concentrations are larger in the Forth/Clyde axis than elsewhere in Scotland; it also contrasts with that of wet-deposited acidity, the product of acidity (H^+ concentrations) and amounts of rain (Figure 5). The largest amounts of wet-deposited acidity are found in heavy rainfall, high altitude areas, viz. the Lake District of England, the southern uplands and west central Highlands of Scotland. In Scotland, this distribution coincides with the occurrence of slowly weathering bedrocks (gneisses, granites and porphyries).

3.13. In northern Britain, sulphuric and nitric acids contribute 70 per cent and 30 per cent respectively of the wet deposited acidity—figures similar to those obtained in Scandinavia (Overrein *et al.* 1980) and the USA (Galloway and Likens 1981).

3.14. A mean pH of 4.2 implies that a solution is more acid than one with a mean pH of 4.7, but in regard to rain, a mean pH of 4.2 also implies a greater probability of an extremly acidic event of great biological significance occurring than would be the case with a mean pH of 4.7. Observations made by members of ITE indicate that these acidic

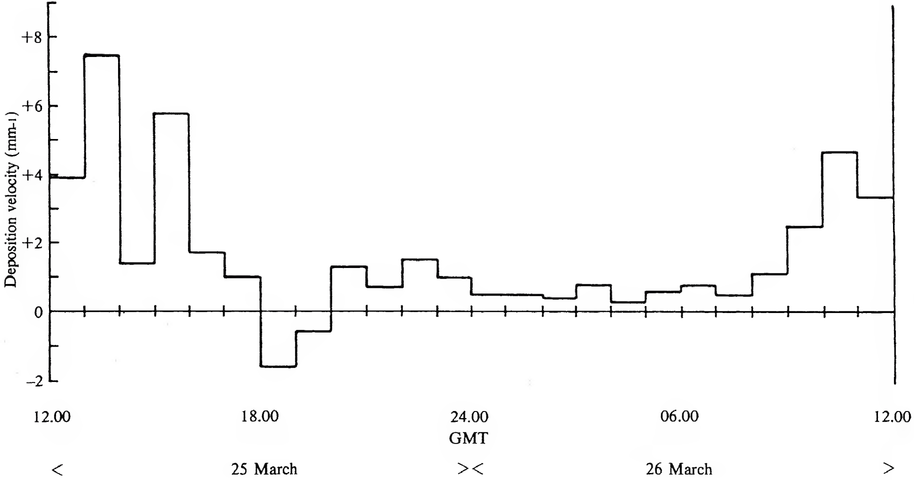

Figure 3.
Changes in the rates of SO_2 dry deposition to the canopy of a Scots pine plantation at Devilla, Central Scotland (25/26 March 1982). (Positive deposition velocities indicate that SO_2 was being deposited whereas negative velocities, as at 18.00 - 19.00 25 March, suggest that SO_2 was entering the atmosphere) (Fowler et al., 1982a).

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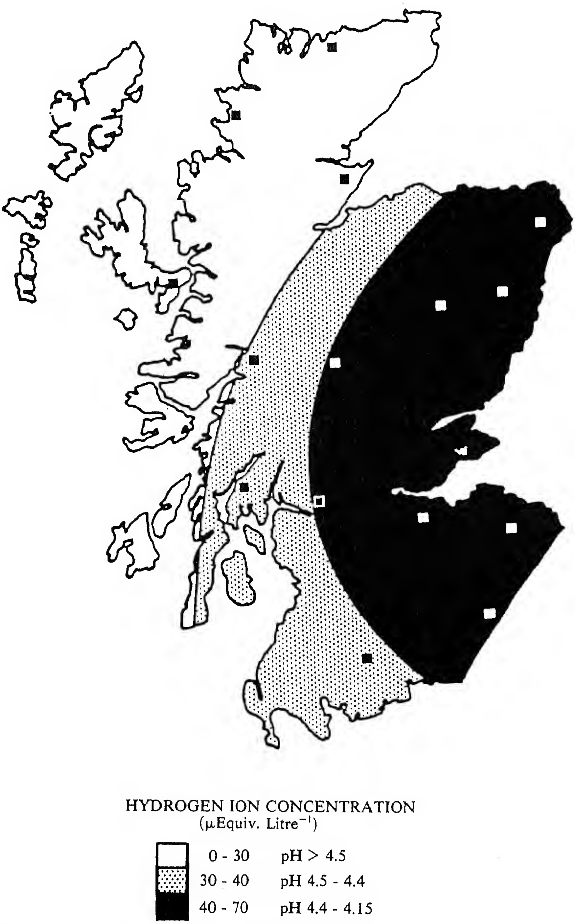

Figure 4.
Mean acidity of rain in northern Britain, 1978-80. Collections at urban (☐) and rural (■) sites (Fowler et al., 1982b).

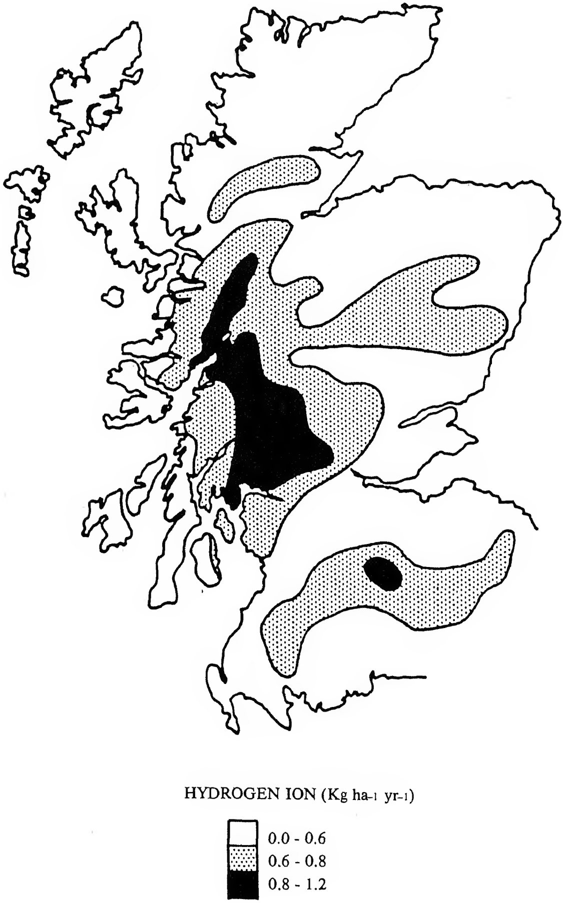

Figure 5.
Annual 'wet' deposition of 'acidity' (Kg H^+ ha^{-1}) in northern Britain (Fowler et al. 1982a).

episodes in northern Britain are associated with air masses that have travelled from the major industrial regions of England and continental Europe. In Central Scotland, 30 per cent of the annually deposited wet acidity was attributable to rain falling on 5 days (Fowler & Cape 1984). In Scandinavia, most of the soluble pollutants in accumulations of snow are removed in the early snowmelt, which is sometimes very acidic (pH 3.2).

3.15. In Britain, it is essential to install a comprehensive rain (precipitation) collection network suitable for the determination of acidity and the measurement of concentrations of the different constituents, natural and man-made. Regrettably we have inadequate historical records of the chemistry of rain. For the future, an appropriate rainfall network should indicate how changes in the use of fossil fuels are reflected in changes of rain chemistry, knowledge which would be desirable when considering emission standards.

3.16. Despite our less than perfect knowledge, it is obvious that the contributions of wet and dry deposition to total acidic inputs differ in different parts of the UK. Dry deposition is more important near large conurbations and centres of industry, the major sources, whereas wet deposition gains in importance in areas where annual rainfall is heavy.

4. RESEARCH ON THE ENVIRONMENTAL EFFECTS OF ACID RAIN

4.1. *Effects on terrestrial ecosystems*

Fumigant effects: Research, mostly done in the UK, has shown that plant growth can be decreased without the apppearance of obvious blemishes. It has also been found in Britain, and elsewhere, that the damage done by mixtures of pollutants cannot be predicted from the effects of pollutants acting singly. Thus, at concentrations at which SO_2 decreases plant growth, NO_2 alone may stimulate growth; in mixtures with NO_2, however, the damage done by SO_2 is sometimes significantly increased (Whitmore and Freer-Smith 1982).

4.1.1. Much, if not most, of the effects research done until recently overlooked the first principle of pathology, namely, the need to isolate and characterize the agent or agents causing damage. Thus, instead of investigating the "pollution environment", most assumed that the damage they observed was attributable to SO_2. Research done at Lancaster University, ITE and Imperial College has resolved a previously irreconcilable effect. Effects in the field could not be "reproduced" by fumigating plants with SO_2 injected into clean, filtered air. It is now realized that NO_x, ozone, and probably other pollutants (fluorides, hydrocarbons) can alter the impacts of SO_2 significantly, usually by intensifying them. Further, it is now appreciated that earlier references to ambient concentrations of x_1 ppb SO_2 m^{-3} should have been interpreted to include x_2 ppb NO_x m^{-3}, x_3 ppb O_3 m^{-3} etc., the balance changing diurnally and seasonally. The implications of x ppb SO_2 m^{-3} in one part of Britain probably differ from those of the same concentration in another part—x ppb SO_2 m^{-3} may be accompanied by more or less ozone. There are cetainly differences from country to country.

4.1.2. While something is known, from controlled experiments in laboratories and glasshouses, of the damage that *can* be done by atmospheric pollutants, very little is known about the *actual* effects of ambient mixtures of pollutants in the field.

4.1.3. It has long been known that the different assemblages of lichens occurring on trees reflect the degree of atmospheric pollution, some species being more tolerant/sensitive than others, while Farrar *et al.* (1977) showed that the occurrence of Scots pine used to be restricted in the Pennines by mixtures of atmospheric pollutants. Experiments done by ITE suggest that the polluted atmospheres at some sites in the area between Liverpool and Manchester can decrease significantly the growth of some pasture grasses, but, at present, it is impossible to give realistic estimates of the extent of damage.

4.1.4. It is sometimes said that small concentrations of atmospheric pollutants may be beneficial, oxides of nitrogen acting as nitrogen fertilizers and SO_2 possibly minimizing sulphur deficiencies that might otherwise occur on intensively cultivated land. However, the same benefits could readily be obtained by returning to ammonium sulphate fertilizers.

4.1.5. For its part, ITE has developed a system of modified open-top chambers, examining the effects of ambient, and filtered ambient, atmospheres on plant growth while allying itself with colleagues in (a) the School of Agriculture, University of Nottingham, working with a field fumigation system, and (b) School of Biological Sciences, Lancaster University, who have a series of glasshouse fumigation chambers. Each approach has its advantages and disadvantages, but with so much uncertainty about the effects of peak concentrations in relation to mean concentrations, of the changing sensitivity of developing annual and perennial plants (including trees), and of the influence of the physical environment on the sensitivity of developing vegetation, it is essential to maintain a range of options.

4.1.6. The programme outlined in 4.1.5 does not preclude the development of more fundamental studies which may help interpret, or even anticipate, the incidence of severe damage. At ITE, changes in the surface structure of needles of Scots pine have been investigated, the surface "carpet" of very small wax rods deteriorating sooner in polluted, than in "clean", atmospheres. Perhaps too little use has been made of biochemical indicators of atmospheric pollutants, for example the enhanced activity of some enzymes (in particular nitrite reductase in plants exposed to NO_2), the accumulations of sulphur (in plants exposed to SO_2) and the loss of calcium and magnesium from foliage exposed to ozone. Further investigations may identify other possibly diagnostic features.

4.1.7. In the Federal Respublic of Germany, and elsewhere, forest dieback, notably of silver fir (*Abies alba*) and Norway spruce (*Picea abies*) had been attributed to acid rain. Circumstantial evidence strongly suggests that ozone may be implicated, and, if this were so, it would have major implications for methods of amelioration. As already mentioned, man-made ozone is formed by a photochemical reaction involving NO_x and hydrocarbons, the reaction proceeding faster in warm, than in cold, weather. Significantly, the vehicular emissions of NO_x have increased in the Federal Republic by 77 per cent during the last 15 years. While the cooler and duller weather in Britain may afford us some protection from augmented concentrations of ozone, it would be prudent to establish in Britain a network to monitor tree health, in conjunction with colleagues on the Continent.

4.1.8. In the USA and elsewhere, there is evidence of a direct effect of ozone on annual crops. The possibility of a similar occurrence in Britain necessitates further observations of the type already initiated in south-east England by Imperial College, London.

4.2. *Effects of acid rain* (sensu stricto)

4.2.1. There is no *field* evidence, in Britain or elsewhere in the world, of direct and damaging effects of acid rain on the macroscopic growth of terrestrial plants. However, foliar damage has been recorded in glasshouse/protected environments when applying unrealistically large amounts of unduly acidic simulated rain.

4.2.2. The earlier suggestions that acid rain was damaging the growth of forests in Scandinavia and North America have not been subsequently supported. However, there is evidence from Scandinavia suggesting that some soil properties are being affected. The implications of these changes on the ability of affected soils to carry vegetation are unknown.

4.2.3. Where rain falls on evergreen conifers, there is consistent evidence to show that its chemical composition is modified before reaching ground as throughfall (drips from foliage and branches) or stemflow (water flowing down stems). At the Devilla site already mentioned (Scots pine, 28 years-old), the average pH's of incident rain, throughfall and stemflow were 4.2, 3.7 and 3.3, while at Beddgelert (Sitka spruce, 40 years-old) they were 4.7, 4.1 and 3.6 respectively.

4.2.4. Increased acidity is attributed to the removal of (a) pollutants deposited on foliage during dry intervals and (b) leachates washed from foliage by the increasingly acid water. It has been conjectured that 32 per cent of the sulphate-sulphur reaching the forest floor owes its origin to incident rain, 22 per cent to foliar leaching and 46 per cent to the removal of leaf surface accumulations (Lakhani and Miller 1980; Nicholson *et al.* 1980*a*). However, while these figures need confirmation, and while some of the effects of evergreen coniferous canopies are in dispute, studies of soil processes indicate that it is essential to look more closely at the whole range of elements dissolved in rain, throughfall and stemflow. This research is being done in an extended series of observations being made by ITE, and including Norway spruce (*Picea abies*), the deciduous conifer larch (*Larix decidua*), oak (*Quercus petraea*) and alder (*Alnus glutinosa*). During winter, the sulphate-S concentrations analysed in throughfall collected beneath Scots pine and Norway spruce were significantly larger than those found beneath oak and alder, which in turn were two to three times larger than those in rain. Throughfall collected from stands of trees is also being compared with that from short upland vegetation. Is the throughfall from evergreen conifersrs more or less acid than that from deciduous conifers, deciduous broadleaved trees or short vegetation? If so, what should be the management implications?

4.2.5. In considering the pollutant inputs into soils, it is now obvious that attention must be focussed on the chemistry, and spatial distribution, of throughfall and stemflow. Acid inputs to limestone soils would be neutralized by the release of calcium without markedly affecting soil properties. At the other extreme, strongly acid soils will similarly remain little affected, but, in between, some moderately acid soils overlying slowly weathering bedrock may be appreciably altered with the loss of calcium and magnesium and the release into soil solution of aluminium and other potentially toxic heavy metals. These possibilities are being investigated in collaboration with Aberdeen University, recognizing that the different horizons within a soil profile may respond differently.

4.2.6. With colleagues in the University of Lancaster and the Central Electricity Research Laboratories, Leatherhead, members of ITE are proposing to investigate the effects of soil pollution environments (wet and dry deposition) on the activities of selected microbes, including fungi that form root associations (mycorrhizas) that benefit the growth of trees. Whereas acid rain (*sensu stricto*) does not seem to affect the decomposition of leaf litter, this microbial process is sensitive to gaseous pollutants.

4.3. *Effects on aquatic ecosystems*

4.3.1. There is increasing evidence, notably emanating from Dr Battarbee of University College, London, that assemblages of freshwater diatoms in some parts of Britain overlying slowly weathering bedrock, and in areas receiving large amounts of wet deposited acidity, have altered since the onset of the industrial revolution. One hundred and fifty years ago the assemblages were dominated by acid-sensitive species which have now been largely replaced by acid-tolerant species, the changes indicating that acidity has increased from pH 6.0 to 4.5. Members of ITE are now examining critically the records of Scotland's estates in relation to catches of fish. Other evidence, obtained by some of the Water Authorities, shows that streams and rivers can be subject to acid "surges", particularly after spells of dry weather.

4.3.2. Unfortunately, it will not be possible, except in one or two exceptional instances, to relate changes in fish populations to changes in water chemistry, because assessments of water quality, made by the Water Authorities and their predecessors, rarely included observations of remote minor sources, often used by fish as breeding sites. For the future, the Water Authorities should be encouraged to monitor water quality at a range of locations chosen to include likely fish breeding grounds and other locations of conservation value in addition to abstraction points for potable water etc.

4.3.3. Unlike the situation in those parts of Scandinavia and North America where the occurrence of acid rain (*sensu stricto*) is associated with changes in aquatic biota, including fish, the areas potentially at risk in Britain have been, and will continue to be, subject to major changes of land-use, with the conversion of natural and semi-natural grasslands to plantation forests.

4.3.4. In the west central Highlands, Harriman and Morrison (1980) of the Freshwater Fisheries Laboratory, Pitlochry found, when investigating a number of mini-catchments, that streams draining catchments that had been afforested with evergreen conifers for at least 25 years were more acid than streams draining unafforested catchments, the change being reflected in changed species assemblages of freshwater insects.

4.3.5. If the changes where evergreen conifers have been planted on soils overlying slowly weathering bedrock subject to large wet acidic inputs are found to be widespread—checks are being made by the Freshwater Fisheries Laboratory and ITE—it would be necessary to question the role of land-use changes in addition to the atmospheric distribution of pollutants. Evidence obtained by Maitland of ITE, when studying the upper tributaries of the River Tay, indicates that afforestation with evergreen conifers exacerbates water acidity and alters assemblages of aquatic insects more than other land uses.

4.3.6. The stages in the transfer of deposited acidity from vegetation to soil to freshwater streams and locks/lakes, and the influence of flow rates, have not been studied in great detail within Britain, but much has been learnt in Scandinavia. From a continuing study of geochemical cycling being done at three sites in collaboration with the Institute of Hydrology, the British Geological Survey, the Forestry Commission and the University College of North Wales, it seems that much depends on the contact time and rates of reaction of soil solution with the solid matrix of soil. Because knowledge of this sort is required for a number of reasons, including (a) the establishment of causal links, and (b) a realistic estimate of the rates of change (reversion), should emissions be abated, the work is being extended by involving the Soil Science Department, Aberdeen University, and by co-operating with the North West Water Authority and the Freshwater Biological Association.

4.3.7. Five to ten years ago, the effects of acid rain on freshwater fish were considered in relation to H^+ concentrations. Since then, acidity has been linked to enhanced concentrations of soluble aluminium and other heavy metals. Our knowledge is largely based on work done in other countries. Because this knowledge is still very patchy, the Institute of Terrestrial Ecology hopes to initiate a programme of ecotoxicology related to acidified waters. This programme is dependent upon a more complete understanding of the many different forms of aluminium (for instance the inorganic and organic monomeric forms) and their possible interplay with other solubilised heavy metals. The programme of ecotoxicology should take note of the possibly episodic nature of enhanced concentrations of toxic substances, relating them not only to critical stages of fish biology but also to the development of amphibia and possibly other animals.

4.3.8. Internationally, the emphasis has been placed on fish and diatoms. However, the responses of aquatic macrophytes and invertebrates should not be overlooked. Perhaps interest in atmospheric pollution will trigger a better understanding of the factors which enable some plants and animals to survive in conditions where others fail.

4.3.9. The undesirable changes recently reported in the chemistry, and biology, of streams in the southern Uplands and west central Highlands closely parallel events in similar habitats in Scandinavia and North America.

5. RESEARCH ON THE LEVELS OF AND MECHANISMS FOR SETTING EMISSION CONTROL STANDARDS IN THE LIGHT OF EVIDENCE ON THE EFFECTS OF ACID RAIN

5.1. Until now, the work of the Institute has been concerned with defining the pollution environment and elucidating the mechanisms controlling (a) the transfer of pollutants from the atmosphere to terrestrial and freshwater ecosystems, and (b) their effects, en route, on plants, animals and microbes, and the chemistry of soil and water. Work done in ITE has helped identify the extent to which the environment is polluted by sulphur and nitrogen compounds, also ozone, as a result of the activities of man. Within Britain, there is increasing evidence of an association between acid waters and large inputs of wet deposited acidity in areas overlying slowly weathering bedrock, the increasing acidity changing the assemblages of diatoms and aquatic invertebrates and deleteriously altering fishery status. However, it is impossible at the present to predict from British data the response of different catchments to different amounts of acidic inputs—attempts have, and are, being made to define this relationship elsewhere, notably in Scandinavia. If an emission control standard were to be established in relation to acid rain (*sensu stricto*), it should be aimed at events occurring in sensitive areas, which in Britain are mainly in the remote uplands. Experience suggests that it would be some time before water quality would "improve" following a decrease in acidic inputs, the recovery time being dependent upon the natural cycling (geochemical) of calcium, magnesium and other elements. In the event, the problem in sensitive areas may be exacerbated by afforestation with evergreen conifers.

5.2. There is no field evidence of a direct effect of acid rain on terrestrial plants. It is known that a wide variety of terrestrial plants can be damaged by gaseous pollutants, singly and in combination, but the extent of "damage" in the field has not been assessed except in relation to lichens. The relationship between the occurrence of different lichen species and the atmospheric loads of pollutants associated with different concentrations of SO_2 (an atmosphere with x_1 ppb SO_2 also has x_2 ppb NO_x, x_3 ppb O_3 . . .) has been known for many years. This is the nearest to a dose response relationship in the field: it could conceivably be used to define and monitor emission control standards.

5.3. To be realistic, it should be admitted that, at present, we cannot base a set of emission control standards on known quantitative dose responses of (i) plants and aminals, (ii) soil and water, and (iii) terrestrial and aquatic ecosystems, to acid rain, whether used to imply wet deposition or wet and dry deposition. However, we do have sufficient knowledge to devise effective ways of monitoring changes that may occur if emissions were to be controlled.

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Examination of witnesses

DR J C BOWMAN, Secretary, PROFESSOR F T LAST, NERC's Institute of Terrestrial Ecology, Bush Estate, Edinburgh, DR D J J KINSMAN, Freshwater Biological Association, PROFESSOR H G MILLER, Department of Forestry, University of Aberdeen, and DR P J W SAUNDERS, NERC Headquarters, Natural Environment Research Council, called in and examined.

Chairman

518. Dr Bowman, may I begin by asking you to introduce yourself and your colleagues to the Committee?

(Dr *Bowman.)* I am Secretary to the Natural Environment Research Council based in Swindon, with responsibility across the whole environmental field. On my far left is Dr Saunders of the Science Division Headquarters covering various policy matters. On his right is Professor Miller of the Department of Forestry, University of Aberdeen, who is with us primarily because we as a research council support research in the universities and so have quite a university community who look to us for their funds in doing work of relevance to your inquiry. On my immediate right is Professor Last, Assistant Director of the Institute of Terrestrial Ecology, one of the constituent institutes of the Council. He is actually based at their station in Edinburgh. On my far right is Dr Kinsman, Assistant Director of the Freshwater Biological Association, who is based at their laboratory on Windermere. We have between us a fair range of scientific disciplines of relevance to the inquiry.

519. First of all, may I thank you very much for your helpful report which you submitted for our study beforehand. As I understand it, the area of your research is concerned more with the effect of acidification rather than ways in which it can be controlled or prevented?

(Dr *Bowman.)* That is correct.

520. We will bear that in mind in the questions we ask you. If I may do something unusual, rather than go through the report logically from beginning to end, I would like to start at the very end, with the very last sentence, which I will read out for the record: "Generally, we believe acidification as a result of man's activities is a serious problem which must be tackled effectively if we are to prevent serious and possibly permanent damage to the environment in the longer term." That is the most forthright statement we have received from any British scientist who has so far come before us, probably because you have no interest other than that of pure science to promulgate. (I am not sure if that is a proper comment to make.) Do you consider there is evidence of damage already in the United Kingdom or simply that we are at risk?

(Dr *Bowman.)* Could I ask Professor Miller to answer your question?

(Prof *Miller.)* We see no evidence at all of damage to trees or to vegetation. There is concern about possible damage to fresh waters and to their biota, at which point I should pass it on to Dr Kinsman.

(Dr *Kinsman.)* On the fresh water side, the particular area which I am familiar with is the Lake District, and certainly the factual evidence to date gives us no grounds to make any statement that there is any fresh water body, stream or lake in the Lake District showing the effects of acidification over the period for which we have data.

521. None at all?

(Dr *Kinsman.)* None at all, but there is evidence in Scotland, and Professor Last will deal with that.

(Prof *Last.)* My comments might seem to be in conflict with those which have just been made by Dr Kinsman, but it needs to be pointed out that in fact the pollution environments in different parts of Britain differs appreciably and interplays with other aspects of the physical environment. With that piece of understanding, there is undoubtedly evidence that some waters in Scotland have become acidified over the course of the last 120–130 years, and I am thinking of waters in the Galloway area. We have suspicions that such changes may be occurring in similar sets of circumstances elsewhere. We have got one or two instances which we have now recorded, and it is necessary, I believe, to look very carefully elsewhere to see what is happening.

522. If I might ask about tree damage, what you have just told us conforms very much with the evidence we received earlier this week from the Forestry Commission who say they have not seen any signs of damage to trees in this country. As you know, we have been to both Germany and Scandinavia and there the evidence given us was that in some instances there was some evidence of damage many, many years ago but not a great deal of notice was taken

[Chairman *Contd.*]

of it because there had been cyclic instances of damage to particular kinds of trees going back over centuries, but suddenly within the last two to three years damage had become evident on a catastrophic scale. The question we asked the Forestry Commission, who were unable to help us since they were not themselves conducting research, was whether we could be in the situation that, say, Germany and Scandinavia were in 10 or 15 years ago; in other words, could damage be occurring though it is not evident and could we be at risk of a sudden change?

(Prof *Miller.*) Clearly, we have to think about this and it depends very much on the reasons one accepts for the observed damage in Scandinavia and Germany. As you know, there are two approaches: one is that damage is working from the soil. We could pursue that later, but for the moment we think it less likely as an explanation. The other is that it is a gaseous factor, implying the existence of stable atmospheric conditions with good sunlight for the production of ozone. It is hard to see in the afforested areas of Scotland weather conditions as stable as that, and for that reason we think it unlikely, though we have to keep our eyes open.

523. If I have understood it correctly, what you are saying is that if the main cause of the forest damage which has been experienced in the Black Forest in recent years is ozone, which seems to be the way the Germans are thinking at the moment, we are in the fortunate position of suffering from typical rainy conditions, with not so much sunlight and anticyclones, so we are unlikely to go through that kind of experience?

(Prof *Miller.*) Yes, together with the fact that in central Europe there is a build-up of this pollution from many different sources, whereas we are on the edge of this polluted environment.

Mr Taylor

524. Professor Miller said there were two possible means of transmission of the pollutant: one was through the soil, which in his judgment he thought less likely, and the other alternative means of transmission was the gaseous one. I thought he concluded that was also unlikely?

(Prof *Miller.*) No. I concluded that if that was the cause of the pollution in Germany we would be unlikely to see the same conditions occurring in this country on the same scale because of our different meteorological conditions.

(Prof *Last.*) I would like to support and amplify the comments made by Prof Miller. Again, on the continent please accept there is a great variety of pollution environments. As he has said, there have been two explanations which have been put forward for the death of trees in Germany, and of course more recently there have been similar instances in Vosges in France, then moving up to Scandinavia. Many of us believe—and I would stress "believe" because in fact our continental colleagues have not done experimental work—it is unlikely that the damage is attributable to acid rain in the strict sense. We think it is more likely to be attributable to ozone, and we have a number of reasons for believing this, not the least of which is by looking at comparable instances of damage in the United States where proof has been obtained of ozone damage, and that type of ozone damage relates to that which you can see in parts of Germany. Prof Miller rightly suggested that we in this country were less likely to experience this problem because we do not have the sunlight and warm temperatures which are necessary for the transformation of oxides of nitrogen into ozone. However, I do believe it is important for us to talk, not about what has happened on the continent but about the structuring of a survey, which is continuous over a number of years, so that if such damage is occurring in Britain we can identify it at an early stage.

Chairman

525. As a result of the answers to our previous questions I was beginning to form the conclusion that the last paragraph of the report which talks of serious problems and preventing serious and possibly permanent damage to the environment would not necessarily refer to forests, but now Prof Last is adding the caution that that last sentence could apply to forests?

(Dr *Saunders.*) Could I say as author of the document that in reaching our conclusions we have brought together a number of strands that relate to acidification of the environment, and acid rain is only one of the factors. I think intensive land use and intensive afforestation particularly in the acid bedrock areas of Scotland and the north, are possible sources of acidification in catchment areas. A number of issues are involved and one has to try to separate the strands. In terms of acid rain and gases, we do not think that it is likely to be the explanation for forest damage; we think ozone is what we have to watch out for, and that occurs more in the south.

[Chairman *Contd.*]

526. If we go to forests and go to the other things you mentioned earlier, acid precipitation, which I take it is a term you would prefer rather than "acid rain", is a very serious problem insofar as waters are concerned and the effect on water ecology and fish life. Is that correct?

*(*Dr *Bowman.)* If I might comment before Dr Kinsman comes in, without wishing in any way to disagree with Dr Saunders in answer to the last question, by way of clarification I think the earlier question you put to us was in relation to ozone damage in forests. In terms of acid precipitation, we are looking at a whole range of consequences for the environment, so the final sentence in our submission we believe to be correct in terms of acid precipitation effects. In terms of ozone effects in this country, we may not suffer badly from that particular aspect of the general acidification problem in the environment. I think that is where the difference arises between perhaps a view that our statement is over-stated, if you like, and our view that in fact it is correct to make that statement.

Mr Alton

527. From what you were saying, it struck me you were implying that perhaps we could afford to be complacent because it does not affect this country particularly and, unlike the Germans who are pumping millions of Deutschmarks into the installation of desulphurising equipment in industry, lead-free petrol and lead catalysts into motorcars, we do not need to do that; it will not affect our forests and waterways?

*(*Dr *Bowman.)* I was not trying to imply that and I am sorry if I have not made myself clear. I implied that the earlier part of the discussion focussed on ozone damage to forests and the effects observed in Germany and the explanation that the damage observed there was of that origin as far as we could see. What I would like to point out is that there are a number of effects which result from acid precipitation and the effect of ozone on forests is but one other possibility. If you are to make a collective statement, as we do here, you need to look at more than the German experience; you have to look at other effects on the environment in terms of acid precipitation which I am sure we will touch on in the course of questions.

Chairman

528. We have an answer in suspense?

*(*Dr *Kinsman.)* If I still remember the question, one must remember that even in pre-industrial times the natural rainfall was acid and most of the northern part of this country—in fact everywhere north of Watford Gap—was glaciated and the soils were straight minerals until about 15,000 years ago. The naturally acid rainfall led to the acidification of soils and the development in some places of small acid streams and lakes as a natural development of the acidification of soils and the building up of acid soil profiles. Our work on the pollen contained in mud profiles at the bottom of lakes gives a good history of the slow development of the natural acidification of surface soils, and we would estimate that the most acid natural stream under natural rainfall conditions—pre-industrialisation—was probably about pH5. Intriguingly, many animals are not significantly distressed at pH values of that kind and most fish survive down to pH5–5.5. We now have in the Lake District and in various areas of Scotland a significant number of small streams and water bodies with pH values more acid than this—typically, four point something—and natural animal communities did not evolve to live in those conditions. Those are the conditions in which we find a lot of animals and fish stocks missing. The probability is that in time we will develop more of these acid waters.

529. Then if that is the case do you believe that we should consider controls on emissions? Would that have the effect of preventing further damage, further acidification? Would it reverse the process?

*(*Dr *Kinsman.)* I think if one were to keep adding acid at the rate that we are then the probability is that there will be more acid environments developed with time. That is the only answer I can give you as a scientist. On the first question you asked, I can only answer as a voting citizen.

Mr Alton

530. I would like to question you further on that because the Chairman's question was pretty specific. Are we going to achieve the objective of removing acidification and are we going to reverse the process if we were to spend a lot of money on controls?

*(*Dr *Kinsman.)* That is the other side of the coin. Presumably, given enough time that would happen. In certain environments it might happen almost immediately but one would guess that in most environments where there are acid waters now, it would probably take decades to centuries. That is purely a hunch. We do not really know. As

[Mr Alton *Contd.*]
to why the Lake District may not be showing significant effects, intriguingly almost before anywhere else in the UK, Barrow and Dalton were the biggest ironworks in the world 200 years ago and it may be that the Lake District was acidified very early on and is still at the same sort of level.

531. Surely, though, industrialisation has hit that part of the world probably more than anywhere else and in probably the last 20 years the levels of sulphur dioxide have actually declined. Has that had any effect at all?

*(*Dr *Kinsman.)* Early on the fallout was probably local because of low stacks and so on. What we see coming to the Lake District now are air masses derived from much further afield.

Mr Miscampbell

532. Can you help me with this. You say we now have certain small streams where this is clearly an identifiable problem. How long have you been alerted to this identifiable problem? Is it something like in Norway, where it has come up since the late 1950s, or are you saying these streams were acid before the war or acid before the first great war?

*(*Dr *Kinsman.)* All the evidence the FBA has for the Lake District shows the streams we found were acid 50 years ago are still acid now but not any more acid than they were 50 years ago.

533. Have you any streams you would add to them that were not acid 50 years ago you may be able to show directly is a sign it is slowly increasing?

*(*Dr *Kinsman.)* No evidence from the FBA.

534. Galloway?

*(*Dr *Kinsman.)* Prof Last will be able to answer on Scotland.

Chairman

535. Have you carried out diatom analysis in the Lake District?

*(*Dr *Kinsman.)* On some lakes, probably not the most sensitive ones.

536. Because that would indicate the length of time they have been acid, would it not?

*(*Dr *Kinsman.)* Yes. I think the RAF Air Sea Rescue Service as an exercise are helping with this today and I hope we might be able to tell you that next week when you are in the Lake District, but that is in hand.

*(*Dr *Bowman.)* In terms of Scotland the picture is slightly different and Prof Last can speak to that.

*(*Prof *Last.)* As an Englishman I do not know that I should be speaking on behalf of Scotland but I am very happy to do so. I think you are aware of the events in Galloway where there have been these diatom records which have shown changes in the species composition of the assemblages of diatoms over a period of time and that these species assemblages have increasingly turned to those species which are able to survive in acid conditions. But over and above that sort of data, we are now trying to look at estate records. In Scotland estate records have been kept fairly accurately over many years on many estates, but I have to give a word of caution in that, of course, at one stage some of these streams would be stocked and others would not and in some instances streams that were stocked are no longer stocked, but we believe that what we have seen of these records makes it worth our while to investigate them thoroughly to try and detect the change, the loss of fish catches, over the course of years which a cursory glance indicates has happened quite conspicuously in certain areas.

*(*Dr *Bowman.)* You did ask us whether we thought it was desirable to spend money on reducing emissions and so on. Could I generally point to the fact—and I am not in any way wishing to be difficult here—that the role of NERC is to carry out science and to create knowledge and we would not wish to make a judgment as to economic and policy issues, which we see as outside our remit.

537. So you cannot tell us anything about levels of controls or the cost-effectiveness of different levels? You have not been looking at that?

*(*Dr *Bowman.)* In terms of cost-effectiveness, not at all. In terms of levels, I think we can respond to questions as to what the consequences would be of a certain lowering of emission levels, the amount that might be in the atmosphere and the consequences of it for the environment, but whether it would be cost-effective or whether it is desirable to do it is not within our terms of reference.

Mr Alton

538. Dr Bowman, you have indicated the primary responsibility is to carry out

[Mr Alton *Contd.*]

research. Your funds were cut by the DOE in 1980. Since then has that made a substantial impact on your capacity and ability to carry out this kind of work and do you think you are sufficiently well financed to be able to carry out the onerous task which you have?

*(*Dr *Bowman.)* For a number of years we have maintained a programme of research on acid deposition. We have felt—and all this was before I joined NERC—that the amount of money that was being spent on that particular subject was really inadequate in relation to the various problems we perceived, and we did make representations to various departments, to the Advisory Board for the Research Councils, which advises the Secretary of State, DES, on the size and allocation of the science vote, that this was a problem which we thought required more attention. I fear that until relatively recently we did not have any positive response to those representations. I may say in the last 12 months funding for strategic research on this subject has increased very substantially, both from within the United Kingdom and, indeed, from within Europe. Our present view is that we need to take stock of this extra funding and see whether we have resources that can cope with any more than we are currently getting, but certainly there was a long period when we thought there was an inadequate amount of funding and we said so.

539. I did get the impression, it is fair to say, when we were in Scandinavia that they were almost in a sense re-inventing the wheel, because we had been in Germany a few weeks before and a lot of key research that had been carried out there was being carried out again in Scandinavia. Are we going to go through the same process here of again re-inventing the wheel in the United Kingdom and what are you doing to co-ordinate the research which is going on throughout Western Europe?

*(*Dr *Bowman.)* Could I first of all make a general comment and then hand over to my colleagues. This is a question I get asked on practically every subject with which we deal. I may say that the science community is a fairly international sort of community and most scientists like to feel they know what is going on in other parts of the world and NERC likes to feel it has a pretty good finger on the pulse of international science. That does not, of course, prevent scientists from doing their own thing, even if somebody else is doing it as well, but we do have a pretty good picture of what is going on and I think that we have already indicated there are circumstances peculiar to the United Kingdom which mean we really ought to do research on our own problems bearing in mind what other people are also doing. Having made those general comments, could I ask Prof Last to comment and then Prof Miller.

*(*Prof *Last.)* If I can make a comment about cost-effectiveness, Mr Chairman—and I hope that I am not overstepping the mark—it is this: are you correct to be looking at this issue as a matter of cost-effectiveness?

Chairman

540. Governments invariably do and they occasionally need guidance.

*(*Prof *Last.)* Yes. If you look at the situation in Scandinavia, where there is a loss of fish associated with the incidence of acid rain, and if you look at the situation in Germany where there is the death of trees associated with the incidence of ozone, there is no way that you would ever do any sums which would show that abatement policies would be cost-effective. In fact, the issue really depends upon what emphasis the population places upon their environment. So could I make that point, that I think by and large any issue that you are concerned with in relation to control depends upon the value that your constituents put on their environment.

541. I could quarrel with you on that. I think you may be understating the case that could be made. For example, with regard to forestry the premature death or disease of trees could have an economic effect upon those who depend upon forestry as a crop, and similarly fishing industries could be very adversely affected by the death of their fish. Therefore, one may have to weigh the value of that part of the economy against the cost of preventing the damage occurring.

*(*Prof *Last.)* I do not deny those points. If I could go back to the comment I made about our involvement with Sweden and Germany and internationally—the point that was raised by Mr Alton—in fact, a great deal of our research is very loosely co-ordinated with the work that is being done in those countries and I do think one of the features you have to recognise is that the interplay with local conditions has, we suspect, a very profound effect upon the outcome of the damage or the influence of

[Chairman *Contd.*]

pollutants. So please do not think that work being done in this country is duplicating that being done in others. This could possibly be the case but, in fact, conditions do differ and they do differ very much within some of those countries as well.

Mr Chapman

542. Dr Bowman, I wonder if you could be a little more specific and precise. You said until about 12 months ago you felt the research funds made available to you were inadequate. When did you first make representations to the Government or to the appropriate body that you thought you needed more funds?

(Dr *Bowman.*) As I say, Chairman, it was before I joined NERC but Dr Saunders was with the Council at that time and could comment.

(Dr *Saunders.*) Chairman, I was basically responsible for developing the Council's general pollution research programme in 1973 and at that time a glaring gap in the Council's work and in that of the research organisations in this country was the question of whether air pollutants in general were having any impact upon forestry, agriculture and the natural environment. There was virtually no work going on and so the Council set about mounting a research programme with some encouragement from the Department of the Environment. That programme was also designed actually to answer very fundamental questions about the interactions of organisms with their environment, whether natural or modified; this is why we have a very fundamental interest in what is going on and changes in the environment. Like most administrations of the day round about the end of the 1970s, there were financial cutbacks introduced in government departments. I am afraid this was the area, as far as the Department of the Environment were concerned, in which they were unable to fund any further research and there was a major cutback. I should say that we kept in close contact with the civil servants and, indeed, kept them informed as to what we were intending to do and we carried on supporting what we could on the science budget, which within ITE alone would have been in the order of £160–180,000 per annum at present prices. The strange thing is that the European Community's research programme also backed out of the field at the same time. It is now a major priority. Both the Department and the European Commission came back after ducking out for two years.

543. When exactly did they come back in?

(Dr *Saunders.*) Last year. We started negotiating at the end of the year before last for new contracts.

544. So if you had to relate this warming and cooling of Government you could say you first appreciated the problem in the wake of the Stockholm Conference?

(Dr *Saunders.*) Yes, very much so.

545. This set you getting your own programme together and you might say the European body suddenly became very interested at a time when a proportion of the trees in the Black Forest were found to be diseased?

(Dr *Saunders.*) I also think the European Community has to take cognizance of what these inputs show. By then it was getting rather alarmed at the protests coming from the Scandinavian countries. Remember, Denmark is very closely linked to Norway and Sweden through other ties.

546. This nicely leads on to the next question I was going to put to you collectively. You have said you have very good contacts with your equivalent people with expertise in the other European countries?

(Dr *Saunders.*) That is right.

547. It seems from the evidence that we are taking that there does not seem to be a general meeting of minds among scientists, and this was on this whole question of acid precipitation—to the degree that we thought there might have been. You have probably met Prof Rosenquist of Oslo, so I am not suggesting all scientists should agree but there seems to be a great chasm between the collective opinion of scientists in the United Kingdom and the consensus of scientific views in the rest of Western Europe. Do you have any comment to make on that?

(Dr *Bowman.*) Yes, we do, Chairman, and it is that it is not by any means a simple subject when one comes to probe into it. It goes back to the beginning of our discussion, namely, that the discussion focused on one particular aspect which was really rather specific to Germany. If you look at other aspects of the problem they may well turn out to be somewhat specific to other countries in Europe or North America, so

[Mr Chapman *Contd.*]

the reason why you do not see necessarily a meeting of minds from scientists across Europe is that people are looking at their particular patches themselves and trying to elucidate particular local circumstances; the local circumstances are not the same across Europe, so the interpretation of what is going on in the Black Forest and the interpretation of what is going on in Cumbria as against Galloway, for instance, differ. I think to the general public it is a very confusing picture and it is the general impression of scientists arguing between themselves.

548. So scientists are really just like politicians.

(Dr *Bowman.*) I think it is that we are looking at a complex issue and the phenomena we are seeing in different parts of the world are not the same. They are all part of the same complex but the manifestations are not the same in different parts of the world.

Mr Alton

549. If I might pursue that, Dr Bowman, I think Mr Chapman was really probing you on your ability to be able to come to conclusions, and given the evidence you had before you and your ability to carry out investigations, would it be fair to attribute your reluctance and, therefore, perhaps inability to come to conclusions at this stage to the lack of research having been carried out and is that in itself because of the reductions in your research programme? Following on from that, would you say that the Department of the Environment are culpable for that?

(Dr *Bowman.*) Can I take first bite at that, which is a three-headed problem. We have and could put together the evidence and draw certain conclusions from the evidence that we currently have. It is always the case with science that as more information becomes available one can update conclusions. I do not think there is any reluctance, and I am not aware that there is any reluctance, to put together the scientific evidence and to draw the scientific conclusions that one can on the evidence that has so far accumulated. What we have done is to show a complete reluctance, for reasons which I will amplify, if you like, to make conclusions as to whether it is cost-effective to introduce emission controls and so on, but quite frankly those questions are not ones that fall within the competence or the remit of the Research Council to answer because it is not our job to do so. The other point which I think you raised is the question of the DOE and whether it is culpable. I think again I want to duck that question slightly but say to you that in our view, for reasons which we would not necessarily be able to know about, we believe that there was considerable underfunding of vital research through the late '70s and into the early '80s on a problem which the scientific community had perceived, had made known to Government, had said needed more funding and nothing happened. Now, who was really responsible for that I would not like to say. Clearly it probably was a number of circumstances.

550. But the DOE were and are your paymasters. Exclusively, or not?

(Dr *Bowman.*) The Department of Environment are one of our customers. We in fact come under the Department of Education and Science.

Mr Miscampbell

551. One of the dilemmas that we have been facing is that where you go to southern Norway, or Sweden, but particularly southern Norway, so far as rivers are concerned, you find that really there is devastation, not just in a few, but in hundreds and thousands of lakes, and if you fly over them and you look down there are just empty rivers, crystal clear in many cases, but with absolutely nothing in them at all. Faced with that kind of devastation competent scientists over there simply say "Look we know exactly what the problem is and we really do not need to go on very much more". Would you say that if we were facing that kind of evidence here we could very soon say what the problem was?

(Dr *Kinsman.*) I think when you fly over an area today such as Norway or Scandinavia, the Arctic, anywhere, you will see a vast number of very clear water bodies. These water bodies are typically very cold and very low in food materials to make them green as the Thames becomes, so a quite natural condition is for these to be nutrient poor, and very low in animals anyway, even in their unpolluted condition. I think that is an important thing of which to take stock. For many of these rivers and lakes we do lack significant historical measurements, and the evidence that we have to go on is nearly all circumstantial, "I used to catch

[Mr Miscampbell *Contd.*]
fish here sometime ago and I cannot catch any fish now", but there are almost no chemical measurements, and very few pieces of factual information of the sort that a scientist would record at one moment in time and various other moments in time and say "I see evidence from these measurements of progressive change".

552. I think that would be a bit difficult to substantiate with what we saw. I am talking now about southern Norway. They don't complain a couple of hundred miles north—it is that southern sweep where the trouble is. We saw fish farms who had been perfectly happy—and had got full records—to take the water, up to 10 or 15 years ago, and then had to stop it. Now they lime the water to make it all right. I agree, it may have been subtle propaganda—no doubt it was—but they took us to one lovely river, and a lovely house, which had been taken by two Englishmen between 1920 and 1939, whose fishing records were there to be seen, and in 1927 or 1929 the pair of them took 1015 salmon out of the river with two old green rods in 36 days. One of my colleagues said they were barbarians and I think he is probably right, considering the amount they took out, but the evidence is there as to what is happening.

(Dr *Kinsman.*) Yes, there *is* change, but you must remember that those water bodies, because of their natural characteristics, are very sensitive to acidification, and they will slide down a pH scale....

553. They will come down from 5.5 to 5.4, you mean?

(Dr *Kinsman.*) ... they will move very fast, and they will move out of the environmental tolerances of waters in which animals have actually evolved. They are on an edge.

Chairman

554. That brings us back to a question that I was asking earlier which Dr Bowman was beginning to answer which was about the level of controls. Given the United Kingdom situation, what do you feel would be a reasonable level of control that we should aim at for ourselves, first of all, and secondly, how does that relate to the EEC 30 club? Have you any comments to make on that at all?

(Dr *Bowman.*) I think I may have appeared to be beginning to answer it, Chairman, but I do not think we would want to be specific in answer to that question, because there is, from our point of view, not an answer we can give you. We can tell you the consequences of different levels of emission on the environment. Whether or not the cost that would be incurred in reducing or altering those emissions is a cost which it is desirable for the country to spend is not an issue on which we can make a judgment.

555. Those must be political judgments, obviously. All you can do is tell us what the level of emissions is; how you see the effect of those; and how the effects would disappear if we reduced to whatever figure you might wish to put to us. Can I put the question in that way?

(Dr *Kinsman.*) Chairman, it might be that one might ask the question "Should we try to return things to what they were like in pre-industrial times? Is it possible to reduce the acidity of rain if we just think of the acidity now?" If you want to do that, then you need to reduce the acidity by a factor of about four. In other words, to reduce it by a factor of two would be 50 per cent, three would be two thirds, and four would be 75 per cent. 90 per cent would be ten times, so you need to think about it in those terms. If you want to reduce the acidity to a natural sort of environmental level, the emissions that must be removed are really very large, a very large proportion.

(Prof *Miller.*) There are problems too if we were to significantly reduce emissions in that we can offer you no guarantee on changes occurring in the environment. We are not absolutely certain of the processes occurring. We need to know more. In certain cases the amount of sulphur in the soil will have to come through, and this may take centuries. It would be very difficult to guarantee that the money the public pays is going to produce an instant effect, certainly as far as soils and streams are concerned. They would have this effect in those areas where gaseous plumes are important. That would be instantaneous, but we do not think that *is* important in most parts of the country.

Mr Miscampbell

556. We know such problems are infinitessimal apart from what is occurring in the western extremities of our country

[Mr Miscampbell *Contd.*]

and in the north. Do you reckon that the pollution that is occurring there is in fact indigenous, or are we getting it from somewhere else? Is it really the residue from Canada or America, rather than against the prevailing wind our own pollution going there?

*(*Dr *Saunders.)* That is a rather multiple-headed question. If we take ozone, there are periods in which, in the southern part of this country, the conditions build up to a level at which we get inputs of some ozone from Holland and from France coming across; we export it as well if the air mass is drifting in the reverse direction. The big question with sulphur and nitrogen oxide, or sulphur and nitrogen in rainfall is how much is coming from the marine and natural sources. This is an area of great uncertainty. It is an extremely seasonal thing and we are trying to develop work in this area at the moment on the oceanographic and geological front as well, but most of the estimates usually are based on the "Don't know" factor. They work out the emissions from all the countries and then the burdens in the atmosphere; the difference is 10 per cent or so, and it is believed to come from the oceans or across from Canada. I think if you look at some of the plume tracking from the United States, in very stable conditions, it really is amazing how far they travel, and I would not like to hazard a guess at how much, but I reckon we do get a little bit from North America under certain weather conditions.

*(*Prof *Miller.)* We do get Sahara Dust falling in North Scotland, quite regularly, so it is quite possible.

Chairman

557. Yes, but I suppose that given that there is a natural background of sulphur, nitrogen, and the rest of it—nitrogen oxide—in the atmosphere all forms of life have developed a tolerance to those natural levels. What we are talking of is the topping up by man through his various activities of those natural levels, and reaching a point where tolerances cease to exist and really this is what we are talking about—trying to determine what the tolerance levels are and seeking not to exceed them in some way or another.

*(*Dr *Bowman.)* But of course, it is a variety of factors which may be the limiting factor which tips one over the balance, and though I think quite a large proportion of the sulphur dioxide that lands on Scandinavia originates in this country, in fact it is a pretty small amount in relation to that which falls on the UK but because of the local climate circumstances and where they are in the world and so on, that smaller amount has a major effect in Scandinavia so it is a variety of factors—the soil type, and the water and so on—which has to be taken into account.

558. I think that leads us on naturally to another point in your paper, where you discuss the ratios of wet/dry depositions in different regions. What significance have these to the different forms of environmental damage?

*(*Prof *Last.)* If I can answer your question, but also just slightly refer to your previous question, the question referred to the source of acidity from this country or from other countries. As you perhaps will know, the majority of acidity coming in rain at any one location tends to come in very few rain storms, and certainly in Scotland, where we happen to have done a lot of this sort of work, those rain storms will have had trajectories which clearly indicate that they have come from industrial England, France, and the Continent so that in fact, where we have these very large acidic inputs in these few rain storms, they have nearly always come from continental Europe. I am glad you have come to this point about dry deposition as against wet deposition because a place like Galloway, places in the north west Scotland, and so on, would (in your and my terminology) be regarded as "unpolluted", but of course they do have small amounts of sulphur dioxide and oxides of nitrogen and these are being constantly deposited upon surfaces. If you look at the total amount of sulphur or of oxide of nitrogen which is being deposited in remote areas, even in remote areas, dry deposition which is going on constantly is a very sizeable proportion of the total. When of course you get near to industrial areas, dry deposition becomes an even greater proportion of the total. Now, we know that, but what is its significance biologically? I have to tell you that we do not know that at the moment, but we do know that very often, if you get accumulations of these substances in unpolluted areas, when you get rain, that rain will become more polluted as it traverses plant surfaces. More than that, we cannot tell you at the present moment, but I would like to put this point to you: that dry deposition, even in areas where you and I tend to think of the wet deposition as being the prime matter of concern, actually poss-

[Chairman *Contd.*]
ibly accounts for a greater deposition of sulphur.

559. Has the tall stack policy increased these problems in the remote and rural areas?

(Prof *Last.*) Of course, we again do not have historical information, but as you will know, if you have a tall stack policy, there is a probability of your gases staying in the atmosphere for rather longer, and the longer they stay in the atmosphere the greater the probability that they will be converted to sulphate. That being the case, I would by conjecture suggest that the tall stack policy has not greatly affected the amount of gaseous SO_2 in remote areas, but it might have influenced the amount of sulphate.

560. In your description of wet depositions you talk of mists. We have had this defined to us as something different—occult deposition. Have you any comments to make on occult deposition?

(Prof *Miller.*) Yes, we have been looking at this. When I started it was called Scotch mist, but now it has been called occult precipitation for some time. To sketch in the background, and this is a broad generalisation, water will condense around a condensation nuclei and then continue to grow so the smaller the water droplet the more concentrated the dissolved product from that nuclei which is usually sea salt but may be pollution derived or just other things. If one collects this mist, or even just flies through a cloud, one finds that the concentration in the water you collect of all elements, particularly sea salt, is very much higher than if we are looking at standard rain, and there are occasions when it is very much more acid—the base of some clouds can be very acid. Because the base in the clouds is sometimes down around the mountains, the mist in the mountains can be, but not necessarily, very acid, so one can get rather acid occurrences. Though I would emphasise here that there is a little bit of a "thing" running for occult precipitation at the moment. It is not all acid by any means. It is frequently anything but acid. It can be even slightly alkaline, particularly if it is sea-derived or if there is a large amount of terrestrial dust in it. The important thing is it is chemically very much more concentrated than rainfall.

561. We have been given a factor of ten times the acidity of mist which can be that of rain.

(Prof *Miller.*) It *can* be. The emphasis is on "can be". It is not always. It can also be ten times less acid than standard rain.

562. Have you detected any increased damage in areas that are subject to acid mist as a natural phenomenon, or an area where mist exists and which becomes acidified?

(Prof *Miller.*) In so far as my interest has been primarily trees, and I have detected no damage at all, the answer must be no, but whether in fact there is a great probability of getting acid into streams as a result of high occurrence of occult precipitation I do not know. It has been speculated. People do suggest that this aspect of trees filtering the atmosphere might possibly be a way of bringing acidity into streams. For mist—and this is a personal opinion—I think this is a trite explanation. There is a lot more behind it. It is too simple. Areas where we are getting this—yes, sometimes do have more acidity, but sometimes less. I do not think there is any strong feature of acidity that we can bring out at this stage.

(Prof *Last*) I would like to make one comment about occult precipitation, and this is in relation to the Continent. Perhaps as you know, the areas which are subject to it are also very often those areas which are subject to ozone, and it is thought that whilst occult precipitation by itself is unlikely to do appreciable damage, in those areas where we think there is ozone damage, it may exacerbate that damage.

563. As you have brought us back into those areas, would you say hydro-carbons play any part?

(Prof *Miller.*) This is just an area I have been looking into quite closely. The matter that ozone causes damage and causes a loss of nutrients I think is easily accepted. There is, as yet, no evidence necessarily to involve acidity of precipitation. The theory would work quite well without acid precipitation if we accept the simple basic hypothesis. It is not saying that it is not involved—it is just saying that theory does not necessarily require it.

564. I am now asking you about hydrocarbons.

(Dr *Saunders.*) Basically, hydrocarbons are the atmospheric feed stock for ozone formation in the atmosphere, and also for a number of other phyto-toxic compounds.

[Chairman *Contd.*]
My latest information—some work done for the Department of Environment at Harwell—suggests that certainly hydrocarbons are the rate-limiting substances in the atmosphere in the UK and so if ozone has got to be reduced, then that is probably the thing to tackle first.

565. Could I just follow that one up, because I am directly referring to paragraph 10.14 of your paper, where you discuss forest dieback in connection with emissions from motorcars and what we have heard on previous occasions is that motorcars are responsible for a lot of the hydro-carbons in the atmosphere, and also are responsible for some of the NO_x. Would that indicate to you some kind of control of motorcar emissions?

(Dr *Saunders.*) As far as hydrocarbons are concerned, vehicles are probably the main source. NO_x is a little different. However, both are involved in the formation of ozone. The Harwell studies suggest that hydrocarbons are the major cause; the more you put in the more the reaction proceeds. The only other thing I would say is that hydrocarbons are derived from different sources, like spillages of fuel oil from tankers and oil storage tanks. At one time American oil storage tanks were open-topped in areas like Los Angeles.

Mr Chapman: I have the impression that if there is a consensus it is that ozone is the most likely major ingredient of the problem, and that is the subject of our inquiry.

Chairman: As far as forest damage is concerned, yes, but our inquiry is wider than that.

Mr Chapman

566. I am sorry; I should have put that point in. I think I am right in saying we have been told by Warren Spring Laboratories that there is little or no monitoring of ozone in our country. Is that right?

(Dr *Saunders.*) As far as I am aware, at the time of the last retrenchment there were five towns being monitored and some research establishments were running detailed monitoring, but a national monitoring network for ozone does not exist.

567. You think there should be considerably more monitoring of ozone?

(Dr *Saunders.*) We made that statement in relation to water quality and various air pollutants to the Royal Commission, and we have said in here that we are not satisfied at all; the research base is hopelessly inadequate.

(Prof *Last.*) We do not monitor our natural environment effectively. You have mentioned ozone. I believe it is very important to monitor NO_x as well, and also sulphur dioxide and acid rain. We do not have a clear picture. You will have seen that the Warren Spring document in relation to acid rain in the strict sense is a very partial picture. Whether or not it is doing damage, we should know about the occurrence of these things in this country is, and we do not know.

(Dr *Bowman.*) I would add one other thing to the preface to that question. A major manifestation of damage to forests has occurred in Germany, and we have said we believe that is mainly an ozone problem. We cannot indicate how much damage is occurring to forests and all sorts of vegetation in this country which is not manifested in the same way as the damage in Germany. The dry deposition of sulphur dioxide or other atmospheric contaminants on vegetation may reduce the growth of that vegetation, reducing the growth by 10 per cent. If a tree does not grow at 100 per cent but at 90 per cent we are not really going to notice it, but in economic terms it could have a major consequence for, say, crops. There could be an effect on cereal crops. It has been suggested there are effects but they are not well substantiated yet. There could well be effects on the growth of cereal crops as a result of atmospheric contaminants. I return to the point at which we started, the problem in Germany, because that tends to be a rather obvious effect, but there could be many effects, some of which may be obvious to the general public and others which might be classed as much more insidious.

568. I return to what Professor Miller said at the outset of this afternoon's session. Without I hope taking it out of context, he said there was no apparent tree damage in this country. Therefore, you would totally reject the statement made by Friends of the Earth (Scotland) that there are 46 identifiable sites—they brought somebody from West Germany to identify them—showing tree damage?

[Mr Chapman *Contd.*]

(Prof *Miller.*) I would totally reject that claim. Having said that, there are areas of trees which are suffering pollution, mainly in the south of England and areas like South Wales and some parts of the Pennines close to major industrial conurbations. They are not new to us; we have known about them for a long time. The Forestry Commission has not acquired land in those regions since 1925. It is true we do not have a clean environment, but the environment is a lot cleaner than it was when the Forestry Commission decided not to buy land there. For example, in some areas of London certain trees cannot be grown because of atmospheric pollution, and this is not new. How far this effect spreads out from major industrial conurbations is something which is difficult to determine. Ideas come and go a bit. As to trees, I think we can say that the major tree-growing areas in Britain are generally well away from areas where you would expect even a 10 per cent reduction. It is something we must watch out for. As to cereals, this is rather different and I pass it to Prof Last.

(Prof *Last.*) I would take a slightly more cautious approach than Prof Miller. I agree with Prof Miller that the probability of damage being done by ozone to our largest tree-growing areas in the uplands, whether it is in the northern part of Scotland or Britain, is very slight but there are a great many trees elsewhere. My reaction would be to ensure that a comprehensive survey and examination was made. When it comes to other plants, we know from many experiments done under controlled conditions that pollutants can damage plants and, as Dr Bowman has indicated, damage can occur by way of a decrease in growth without obvious leaf blemishes. When growth is decreased very often root growth is diminished rather more than the growth at the top. We know it can decrease growth, but does that actually happen in the field? You were talking of funds for research and so on with colleagues in the NERC, European Community and members of ITE are now trying to structure and set up experimentation in order to try to obtain information indicating by critical experiment what is happening in the field. Viewing it as politicians, you may be amazed at that lack of knowledge at this point and you might have thought we had it but we do not.

569. I am concerned about that but by the by I am concerned about whether you feel you have got adequate funds to undertake the research which perhaps as a matter of urgency you feel should be undertaken in the sorts of fields we have been talking about?

(Dr *Bowman.*) I have indicated the picture which has unfolded over the last few years, and we have received a major boost in funding in the last 12 months. Research is an activity which you cannot just switch on and off; you have to build up a body of expertise, equipment and so on. We are now in the process of digesting that increase in funding, which is very welcome indeed. We want to take stock before advocating substantial increases in funds from those which have now been given to us, because, if I might take the analogy of Nixon and the cancer problem when he threw money at it, you can throw money at a problem but very often you do not have the people there to pick it up and use it sensibly. We are at the stage of having received extra funds but we want to take stock of that increase and see how best to use it. I may say this is a problem we will not lick in 12 months and increased funding of the sort we have now needs to continue for a considerable time with some stability if we are to break the back of the problem; to turn it on one year and turn it off the next is not helpful.

(Dr *Kinsman.*) I would agree with Dr Bowman, if we also include projects in the pipeline not yet funded, of which there are a significant number. The machinery of bureaucracy grinds slowly, whether it is the EEC or DOE. I think I should add the rider that if they become funded we shall be in the position which Dr Bowman mentioned.

(Prof *Miller.*) We will never fully understand the problem or extrapolate to new situations until we understand the processes involved. There has been a great deal of research in recent decades which has looked at situations A, B and C and we understand how they work, but we cannot investigate all sorts of combinations of pollutants of the environment and cannot extrapolate from them until we have done the necessary experimentation.

(Dr *Bowman.*) I would draw a distinction between research and monitoring. As I have said, the NERC is responsible for research; it does not see it as its job to spend science-voted funds on monitoring, and this we would see as the role of other people. Nevertheless, in research it is usually highly desirable to have access to long term records from monitoring and access to a data base is a rather important requirement in carrying out sensible research. We would like to see

[Mr Chapman *Contd.*]
more monitoring done over and above the funds which have now been made available. We would like to see much better and more monitoring in the country than we have at the moment in order to do better research.

Chairman

570. I would like to ask some specific questions on your paper, referring you to particular paragraphs, as there are a number of questions we need to have clarified for the purpose of our report eventually. First of all, in paragraph 10.15 you say that the direct effects of wet deposition appear to be insignificant at ambient concentrations. We have been told that foliar damage has been demonstrated on agricultural crops at pH 4 to pH 4.1 and at lower pH levels recorded in single rain events or occult deposition. Would you like to comment on that?

(Prof *Miller.*) Lesions on leaves are unusual above pH 3.7 and there have been controlled experiments which show them by the time you are down to pH 2.7, but you are right that there are particular species or cultivars of species which, from experiments we are doing in a controlled environment, can be shown to produce lesions when treated with rainwater even up to 4.5 pH, but it is unrealistic to suppose that this is happening in the world outside because there is plenty of 4.5 rain. What is probably absent is evidence in the field of the effect on crops, and even if we actually can trap a concentration of droplets against the hairs of a leaf to produce a small lesion, the probability of that reflecting in a change in yield is not great. Most agricultural plants and crops have considerable loss of leaf. They are, after all, losing a lot to animals and to fungal disease and they are able to compensate for a small loss of leaf, so lesions like that are extremely rare and probably have no yield or economic consequences.

571. Can I turn to paragraph 10.21, where you talk of aluminium being mobilised in high concentrations in acid soils. In Scandinavia it was suggested to us that the slow acidification of soil coupled with high rainfall acidity led to waters in the soil having ultimately a lower pH than 4.5 and at that point they reached a level at which aluminium went into solution and the result of that was fish damage. Is there evidence of this happening in the United Kingdom?

(Prof *Miller.*) It is a matter of what happens in the soil. At around pH 4.5 if you add more acid to a soil in a test tube or more rainfall you will find the soil will resist further change in its own acidity by releasing aluminium. It consumes acidity by releasing soluble aluminium. It is a known fact that most of our soils are below pH 4.5. At the immediate surface of most of our soils in the uplands we are talking about pH 4 or even slightly below, so we are already more within that area where there is a lot of aluminium in the soil. Normally, however, when the water passes on down the soil profile there are reactions with the exchange surface of base minerals to take out into solution calcium and magnesium and the pH rises beyond the magical 4.5 and the aluminium is reprecipitated. This is virtually the formation of podzols. This happens normally with soils. What does seem to be occurring now, and probably will occur to a greater or lesser extent, is the excursion of this aluminium into streams, and that is Dr Kinsman's area.

(Dr *Kinsman.*) To discuss that one must mention that the acidity of a stream is very variable. Most streams are more acid in the winter in this country and less acid in the summer, but there is also an increase in acidity through very high discharge or flood events whenever they occur through the year. Commonly, but not always, when an upland stream is in flood, there is a major increase in acidity. The pH may drop by 1 or 1½ units or something like that and then the aluminium commonly rises at the same time and there are a few occurrences in this country recorded of fish deaths but very few where all these things correlate together in time, extremely few. We do not really know the physiological response of the fish, whether it really is a response to aluminium, and the FBA is doing some research on an EEC-funded project on this problem of aluminium chemistry. It is becoming very apparent that the amount of fluoride present in the water is very important. That tends to lock up a lot of the aluminium, surprisingly, and other chemical components as well. It is a very complicated story. We do not know the answer. It is not as simple as "aluminium kills fish".

572. We have already touched on this to some extent but in paragraph 11.2 you mention evidence from the Freshwater Biological Association that in Cumbria no lake has suffered from increased acidity within the last 50 years, presumably because they had suffered all they were going to suffer anyway

[Chairman *Contd.*]

in the past. Is this generally accepted as a proposition and do aluminium levels increase and/or fish stocks decline within the timescale that we have mentioned?

(Dr *Kinsman.*) I think the answer to both those questions is no, although there is some circumstantial evidence that people say there used to be fish here and there are not fish now, but we have no scientific observations that aluminium has increased, purely because we did not measure it. We have no data.

573. Or changes in the fish stock at all, in the species?

(Dr *Kinsman.*) No. There are two major acid catchments in the Lake District, the Esk and the Duddon. The Esk was the one where Hugh Falkus appeared on television bemoaning the fate of the sea trout. A Report was produced about the fish stocks of the Duddon—an extremely detailed report. You can walk that river system today and look in every little tributary and it is exactly the same as it was in 1899 in terms of stocks of fish. It is a very interesting river with little tributaries, some of which are very acid and the next one half a mile away has very little acid, and you find this one has trout and that one has not. It is exactly what it was like in 1899.

574. Would reversion to a lot of liming of agricultural soil—probably because of the restoration of the agricultural liming subsidy—have any reversal or beneficial effect upon this situation?

(Dr *Kinsman.*) That should have shown up in our chemical records. If agricultural liming had a significant effect on the chemistry that should have shown up in our acid records or calcium records and it does not.

(Prof *Miller.*) I might say that unless the liming is done on stream banks it is hard to see how it would have much effect and presumably the fields that were limed were set some distance back from steep stream banks, so I do not think it is important.

575. You make no mention in your report of any work which you have carried out on the possible effects of acid precipitation upon buildings, corrosion of buildings?

(Dr *Bowman.*) That is not our responsibility.

(Dr *Saunders.*) That is the responsibility of the Department of the Environment and the Building Research Establishment.

Mr Smith

576. My question does not actually relate to the NERC evidence as such but more to the Institute of Terrestrial Ecology paper, which I believe Professor Last might be able to help with. In that you mention that the acidic input in rain in Scotland is greatest in the southern uplands of the West Central Highlands and I wondered if there was any evidence at all or any work being done on what was happening in the West Central Highlands, which presumably from the maps and so on is in the Glen Coe/Ben Nevis area. Is any work being done and is there any evidence of any change in fish life?

(Prof *Last.*) Yes, work is being done by the Freshwater Laboratory at Pitlochry, which is a laboratory of the Department of Agriculture and Fisheries for Scotland. They have worked in the West Central Highlands area near to Loch Lomond on Loch Ard, Duchray Water and Loch Chon. They have done work there and are pursuing that at this time.

577. You make reference in the paper to the work on increased acidity where streams drain through land which has been covered with conifers for 25 years. Is there any additional work to what they are doing on any increase in acidity due to other factors?

(Prof *Last.*) Yes, they are greatly extending that work. Firstly, they are extending it to other locations to be sure that, in fact, the observations that they have made within the Loch Chon/Duchray Water area were not just specific to that area, so they are extending it and are looking at the nature of the acidity which is being generated by looking at the input from wet deposition and from soil-generated acidity. There is another project I know Prof Miller has been involved in at Balquhidder and he might like to comment on that.

(Prof *Miller.*) We are working at Balquhidder with the Macaulay Institute for Soil Research at Aberdeen. We have had large sums of money from the Department of the Environment specifically to look at the passing of acidity through forests and forest soils into streams, to attempt to determine which factors are leading to this. May I go off slightly to the ITE maps. One has to be a little cautious as to how to interpret the amount of acidity and concentration of acidity. Many of the reactions are concentration dependent rather than amount dependent. What *is* amount dependent is the sulphur levels you find with the acidity

[Mr Smith *Contd.*]

and those tend to exacerbate the passing of acidity through soil into streams. So, we have these two factors. We have to weigh them up and whether one is more important depends on what we are talking about at the time.

578. If I might ask what is, I suspect, a leading question but I would be grateful if you could answer it if you feel able, in those areas of the Central Highlands of Scotland which you have observed do you have any cause for concern at the moment about changes in fish stock or loss of fish stock?

(Prof *Last.*) Clearly the work that Pitlochry have done has shown that a set of factors are associated with the loss of fish. They have done this in a particular area. It is now necessary to look elsewhere with a degree of urgency and see what the situation is and then judge it in that way, Pitlochry has produced evidence. Does it relate to a specific incident or is it representative of a more widespread occurrence and according to the outcome of that series of observations, so you come to a judgment of the sort you have required.

Mr Miscampbell

579. Could I ask one question purely for interest rather than scientific inquiry. Is it the position with the Duddon, for instance, that when you looked at the 1899 survey did that deal with fish stocks as well as just fish being there? Have you any comparison on the fish population in the Duddon today as compared with what it was 85 years ago?

(Dr *Kinsman.*) Not really quantitative information, no, no we do not. I think fish stocks are a very difficult thing to work on and one has to remember that most of these rivers in which salmon and trout occur are typically upland rivers. They are very flashy—they show great changes of flow in response to rain, and there are many factors which affect the recruitment and the development of a fish population. As an example, for the last two years, 1983–84, in the Lake District, many of our upland streams have lost their complete trout population purely because of drought. We have had three months of dry weather and the streams have dried up and the fish have died. The same thing happened last year. It is nothing to do with acid rain or whatever. Many of these environments are very unstable. Also, they are chemically unstable, and many of the animals which live there are having a tough time anyway without having the effects of manmade pollution imposed on them as well.

580. Can we say that the Duddon does have respectable trout stocks at the moment, forgetting the possibility of damage over the last two years, or not?

(Dr *Kinsman.*) It has in its lower part, where the pH never falls below about 5.7, and it has reasonable sea trout stocks. They seem comparable in a very unquantitative sense with what was there at the turn of the century, but nobody really did any counts and nobody is in fact doing any counts now.

581. Of course, they may be stocking now.

(Dr *Kinsman.*) I do not think the water authority is stocking. I do not think so.

(Dr *Bowman.*) I just wanted to make sure that we had conveyed to you and your colleagues the fact that we see no conflict between the findings that the FBA have that there is no change in acidity over a long period of time in the waters they have looked at in the Lake District, and the findings in Scotland, where there has been a change, and though I know that others think that this is evidence in conflict, we do not see a conflict in it, and we can see interpretations though we cannot be sure whether they are the right ones.

Mr Taylor

582. I suppose my question is again directed to the Lake District and Dr Kinsman. May I be permitted to say that in an observation of these things, I do not think that 85 years is actually a very long period of time, and the 1899 observation, and the 1984 observation, are both emphatically post industrial! I wonder if I could ask you first whether you would agree with that, and secondly whether there is any earlier data so that we can get three points on our graph instead of just two which are never very helpful, and if there is not any scientific scholarship, or record, is there anything in the folk law? After all, the Lake District has been written about as much as any part of England. If we go back pre-industrial, what do the folk who live there say about their waters, and their fish, do you know?

(Dr *Kinsman.*) I agree with you that the two data points are post-industrial. Two data points are ideal, because they can be fitted to a straight line!

[Mr Taylor *Contd.*]

583. Yes, I don't like linear extrapolations!

(Dr *Kinsman.*) I think the problem is, as far as we are aware, there is no older written information. I do not think, for example, Wordsworth was into describing fish populations....

584. He described a man drowning in Rydal Water.

(Dr *Kinsman.*) That was probably more dramatic. Fish were not of interest to him. I do not think anyone wrote anything about the Lake District. It was one of the forgotten corners almost. I do not know of any information. We have tried to look for this. The only historical information we think we are likely to find is evidence in the sediments on the bottoms of lakes, and as far as we are aware, there is nothing that you can get out of that data bank which relates directly to fish. You cannot find fish scales—they don't preserve. You can find fossilised algae, fossilised invertebrate animals of various sorts, and you can look at the various changes of the chemistry. There is a data bank there. We have done a lot of work on it especially in its older parts; not being particularly pollution orientated that is not our real reason for being. We are very interested in what happened over the last 10–15,000 years. We have begun to concentrate our studies on the upper part of the section—the last one to two hundred years—but at the moment we do not have a great deal of information.

Mr Chapman

585. You will understand that we are receiving a great deal of technical information and advice from very distinguished and expert people, none less than yourselves. I want to put one point: really, the whole thing is encapsulated in paragraph 4.1.7 of the Institute of Terrestrial Ecology's evidence to us on page 12, where it refers to the tree dieback in Western Germany. Basically what I think you are saying—and it was Professor Last who wrote this although it is agreed by you all—is that so far as the forest dieback in Germany is concerned, particularly the Black Forest, you feel that circumstantial evidence strongly suggests that ozone may be implicated, and you go on to say that there is a photochemical reaction between hydrocarbons and NO_xs. If that is right, and I know you have got to cover yourselves, am I right in saying that the problem that Germany faces with its trees, and Scandinavia, will not in any way be alleviated by de-sulphurisation programmes?

(Prof *Last.*) I have to give a guarded answer in that I believe that the answer is probably no, it will not be helped, although if it de-sulphurises it is likely also to slightly diminish the NO_x emissions as well from those static sources. Remember: there are static sources of emissions, mainly sulphur dioxide and NO_x, and then you have vehicular, mobile, sources of NO_x. If you de-sulphurise, I do not think you will have a major influence upon the ozone problem in Germany but I am just slightly guarded in that if you de-sulphurise you are likely also to diminish the amount of NO_x coming from those static sources, but the simple answer to your question is no, I do not think it is likely to but there may be just a fractional change.

586. I take that point absolutely, and of course, we are only referring to the damage to trees, but to put the point the other way, you are not really advocating that if we want to solve the problem of trees, we do not go into spending hundreds of millions of pounds on de-sulphurisation programmes. We perhaps tackle the NO_x hydrocarbons.

(Dr *Bowman.*) But that comes back to the reference to that particular manifestation of damage. If in fact we take into account that there may be damage to the surface of the vegetative parts, and that that then affects growth as well, then the answer to your question in relation to sulphur dioxide would be partially yes—possibly.

(Prof *Last.*) Yes, OK, but I think Mr Chapman was wanting to get my best judgment upon existing information and the balance of it—accepting that it is a judgment without absolute proof—was no.

(Prof *Miller.*) May I support Professor Last on that? The balance of the evidence as we have it at this moment, and you have to understand we are still working in hypotheses—not even theories—and far less established fact, is or does seem to be that it is a hypothesis that is holding together very well, and you are right, that if they were to remove sulphur from the atmosphere, the German trees would still die.

(Dr *Kinsman.*) I think an important point to remember, if you look at the curve of sulphur emissions in this book *here*, is that there have been significant reductions of sulphur emissions over the last 15 years, and over this same period there has been no measurable decrease in the acidity of rain in the country, so there is not a simple

[Mr Chapman *Contd.*]

linkage between the acidity of rainfall and SO_2 emissions. I think that is a very important thing to take on board.

Chairman

587. May I ask you then one final question: the thrust of your paper and of the evidence that you have given us today is that there are still tremendous gaps in scientific knowledge and a great many uncertainties also. Therefore a great deal more research still has to be done to find the answers to many of the questions we have been putting to you this afternoon. However, in the light of our present state of knowledge, how long do we still have to wait for research to produce the answers to those questions and secondly, how long can we afford to wait?

(Dr *Bowman.*) I think, Chairman, that I would like to tackle the second half of the question before tackling the first part. I think our impression is that decisions are always made on incomplete evidence and therefore....

588. Balance of probabilities, you mean?

(Dr *Bowman.*)... the balance of risk, in a sense, and it is really the job of the decision maker to decide whether a judgment and a decision and a change is required based on the available knowledge at that time. I think our view is that perhaps there are decisions that could be taken to which we would provide background knowledge and a "best guess" in the form that Professor Last has just been giving to Mr Chapman. Therefore, to do nothing on the argument that more research is required we would not find, I think, any of us, as individuals, a very satisfactory situation. I think that answers the second part of your question. The first part of your question is that it is always very difficult, given a sum of money, to know how much added knowledge it is going to provide, because research is one of those rather unpredictable activities. Nevertheless, with the new levels of funding that we are now receiving, I think that the next five years is going to provide a good many answers to the questions you have been putting to us, and which would help to provide a better basis on which decisions could be made. I do not know whether my colleagues would dissent from that sort of view, but I think five years on, clearly at present rates of research funding, and bearing in mind the money that is being spent in other parts of the world, could provide some answers. I was in the United States earlier this year, and the budget for acid deposition research is something over $6 million, in the year. It is a huge programme and the amount of knowledge that is going to be created by these various programmes is very substantial, and I would think in five years' time we are going to know much better, but I do not think that should be used as an argument for doing nothing now.

589. On that basis, pursuing what you have just said, are you then suggesting to us that we should not wait five years before taking steps to reduce sulphur dioxide in the atmosphere, first proposition; reducing NO_x in the atmosphere, second proposition; reducing hydrocarbons in the atmosphere, third proposition?

(Dr *Bowman.*) I think what we believe, and I would like Dr Saunders to add his comment after I have spoken, in answer to all three, is that a judgment now needs to be made as to whether steps could be taken to alter the emission rates and what the consequences would be and not just to say we should do nothing because we do not really understand it, which so far as we can see appears to be the view that is being taken.

(Dr *Saunders.*) I think, Chairman, my colleagues alongside would agree—those of us that have had to work in the international forum—that it is an impossible situation. We agree with a lot of the data that is coming out of the international programmes, and yet trying to represent the United Kingdom abroad in the present situation is almost impossible. Something has to be tackled. We are exporting emissions abroad—that is another factor that must be borne in mind in this decision, and as a scientist I think I would like to see the right balance struck between the various three levels of control.

590. Refuge is being taken in this country behind the cloak of insufficient evidence. When we are abroad, we are told there *is* sufficient evidence and as a Committee of laymen we find it very difficult to assess whether the statements given to us by various scientists either (a) that there is not sufficient evidence or (b) that there is sufficient evidence should be accepted or not. That is our problem in a sense.

(Dr *Saunders.*) May I just make one point: may I remind you with respect of the situation of lead in petrol. Although the health component is not involved so much

[Chairman *Contd.*]
in this situation there are very distinct similarities. If you look at the arguments about controlling lead in petrol, in the end it was a matter of public and political will; something will have to be done soon.

(Dr *Kinsman.*) I think an important thing to remember, Chairman, is that there may be an argument that perhaps we do not have enough information and therefore more research should be done. That may or may not be the position, and we have also raised the point about monitoring in the country, and that in particular is going to arise if one wants to monitor the effects of any programme. If one makes a decision to reduce any one of the components that you mentioned, or any other one, then one wants to know what one is getting for one's money, if you like. It seems to me that is something that ought to be noted and thought about seriously. We should be measuring the environmental impact of decreased emissions of A, B or C so that some of these scientific monitoring requirements do not end when a political decision is taken, and so that they don't only provide lead-up to a political decision.

591. That is in the realm of further research and further information, but going back to Dr Saunders' point, where he said quite emphatically just now that something has got to be done, given limited resources and the need to order priorities, what would you as a body advise us is the first thing that should be done?

(Dr *Kinsman.*) Reduce vehicle speeds.

592. You would look to the motor first rather than power stations and industry?

(Dr *Kinsman.*) The motor vehicle is a major source of uncombusted hydrocarbons and NO_x which look as though they are the critical bits in the pie. They are the rate-limiting components. If that is true you could increase the sulphur dioxide component in the atmosphere with no significant additional effects.

593. Do you know that the motor manufacturers are totally unaware of it and their scientists say they have read all the available literature and have not come to any conclusion of this kind? We did ask them what literature they had read and they said it amounted to 100 different papers but they listed about five?

(Dr *Bowman.*) Certainly the oil companies are aware of this.

(Prof *Last.*) If I may say so, my colleague has come up with an answer which slightly surprises me, in that he suggested you could cut down NO_x emissions and hydrocarbons in this country at this stage and you could think of them as rate-limiting the oxidation of SO_2 to sulphate.

(Dr *Kinsman.*) Yes, to SO_3.

(Prof *Last.*) In a way, my answer to the Chairman—and here we have personal opinions from two people who have been looking at it from slightly different angles—would be that I would try to do something about the sulphur dioxide concentrations as far as this country is concerned. If I were in Germany I would be very much concerned with vehicle emissions, albeit I accept the point Dr Kinsman has made about the role of hydrocarbons and oxides of nitrogen in rate-limiting their oxidation of sulphur dioxide.

(Dr *Bowman.*) I want to return to the comment that essentially you are taking evidence from NERC and as far as they are concerned we would happily provide a summary of the scientific evidence and a view of the consequences of different forms of action. We have already said that we think there is sufficient evidence on which action should be taken—various forms of action. It is not for us to judge which are the best ones; we do not have all the relevant evidence on which decisions can be made. There is a difference of opinion as to the scientific evidence, but one would need to take into account various cost effects and public attitudes to various sources of emissions, and that is not a judgment we can make.

594. I was really asking you as scientists what your opinion was, given the present state of knowledge, of the damage we are apparently suffering at the moment and therefore what we should be tackling first, or what we should look to tackle first, and then a judgment would have to be made on costs thereafter?

(Dr *Bowman.*) In relation to all three factors which you mentioned in your question, I think there are things which we can say should be done to change the effects on the atmosphere, and the extent of those effects on the environment we could advise on, but whether the Government wants to afford to do all three or two or one is not for us to judge or comment on.

(Dr *Saunders.*) I think one of the important things to remember about the whole area is that there is a variety of options and

[Chairman *Contd.*]

combinations which can be considered, and I think the Committee would need advice from the other experts concerned with the technologies and the costs of implementing them. But I suspect there may be a number of different scenarios to control the various forms of pollution. Some would probably be much better than others. One has to try and work out what maximum economic and environmental benefit of this is going to be achieved by different combinations.

595. I accept that but we have been receiving evidence on those matters and I was merely asking you in terms of observed damage itself the most important thing to look at in order to try and find the money for it?

(Dr *Bowman.*) As I think we have indicated, we can see various forms of damage originating from all the three things you are referrring to.

596. Nevertheless, your conclusion is that we cannot afford to sit on our hands as a nation?

(Dr *Bowman.*) That would be our view, yes.

(Prof *Miller.*) May I add that though one might seek change, change with reasoned haste, not change made in panic.

(Dr *Bowman.*) And it may be, of course, that five years on at the end of the research programme one has to backtrack to some extent in the light of new evidence.

597. Of course. That is a real dilemma that exists. We have been given evidence from the Central Electricity Generating Board that in order to retrofit and deal with sulphur emissions something in the order of £1.5 bn is required. That order of money requires some end product that one can show is worthwhile. That, of course, is the real problem.

(Dr *Kinsman.*) A key scientific point behind Prof Miller's point is that the natural environment is a very resilient organism. This does not mean we must be complacent about it but it is very unlikely that rivers are going to be running at pH 4 on Monday next if we have not done something. There are good scientific grounds for saying the great part of the environment is not poised on an edge somewhere, so this was not just a passing remark of Prof Miller. It is actually based on quite a basic, fundamental understanding of the environment and how it works and its stability.

Chairman: Dr Bowman, may I thank you and your colleagues for coming along and spending so much time with us. You have been so helpful and we are most grateful.

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MONDAY 2 JULY 1984

Members present:

Sir Hugh Rossi, in the Chair

Mr Richard Alexander
Mr Sydney Chapman
Sir Reginald Eyre
Mr Robert B. Jones
Mr Norman Miscampbell
Mr Chris Smith
Mr John M. Taylor

Memorandum submitted by the National Coal Board

Para

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INTRODUCTION

1. This paper sets out the evidence of the National Coal Board to the House of Commons Select Committee on the Environment inquiry into acid rain. It addresses the points specifically mentioned in the Committee Chairman's letter of 23 February, but sets the answers in the context of an overall statement of view on the issue of acid depositions. In particular it comments on proposed European Directives in this field.

2. The Board has always been conscious of its environmental responsibilities, as its record in the fields of mining and land restoration shows. There is no doubt that the burning as well as the mining of coal can have environmental consequences, and the Board has cooperated in the drawing up and implementation of smoke control legislation since the 1950s. A later section describes research undertaken by the Board over nearly twenty years related to the control of emissions from coal-fired plant.

3. Rain is naturally acidic as a result of the solution of atmospheric carbon dioxide. The term acid rain was originally coined to describe wet precipitation, including snow, the acidity of which had been increased beyond this natural level by man's activities, in particular the combustion of fossil fuels. However, in the popular debate a broader definition of acid rain, perhaps more properly acid *deposition*, is gaining currency. This can cover almost all environmental effects of the emission of sulphur and nitrogen oxides from fossil fuel combustion, ore processing etc. or from other, natural, sources. It includes the (generally shorter range) dry deposition of sulphur dioxide, nitrogen oxides, sulphates and nitrates, and is even extended to cover other agents, such as ozone, which are not themselves acid, but may contribute to acid formation and also lead directly to vegetation damage. The blurring of definitions does not contribute to objective debate. In the present case we consider it helpful to preserve distinctions between natural and anthropogenic emissions and between short and long-range effects.

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4. Present concerns over acid deposition in Europe are with damage to aquatic ecosystems, mainly reported in Scandinavia, to forests primarily in Southern Germany, and to ancient buildings. But the relationships between plant emissions and depositions in sensitive areas and between depositions and the various observed symptoms have not been clearly established. There is clearly a distinction to be made, for instance, between short and long-range effects. A great deal of work is in hand in these areas. The Board has not carried out any significant work of its own on these relationships although it is sponsoring research as discussed below (para 47), so comments are based on published data. Appendix 1 sets out some of the more important items.

5. There is clearly no broad agreement on whether generalised emission controls would lead to significant amelioration of the observed symptoms and, if they would, whether they would be the most cost effective means of achieving such amelioration. Evidence suggests, for instance, that forest damage and certainly building damage, owe more to local conditions and emission sources than to the long range transport phenomenon, acid rain.

6. The Board does not adopt the view that no action can be taken until all the answers are known. That time may never come. It does, however, feel strongly that decisions on environmental action must always be based on the best available data and applied in the most cost effective manner. We are concerned that a number of bodies and institutions, including the European Commission, appear to have interpreted the available data in a selective manner, and that the Commission, in proposing controls, has given insufficient consideration to costs or likely benefits. It is in an effort to add to the data available, and hence in the hope of improving the quality of decision making, that the Board is encouraging and supporting work aimed at clarifying the relationship between emissions and observed symptoms, while at the same time working to identify and develop, often in cooperation with others, the most cost effective means of reducing the emissions of the potentially harmful products of coal combustion should this be necessary. This work is described in a later section.

THE OCCURRENCE OF SULPHUR IN UK COAL

7. The average total sulphur content in all UK coals as supplied is 1.5 per cent. Averages by producing area are given at Appendix 2. Only Scotland and South Wales have substantial tonnages with total sulphur below 1.0 per cent. The central coalfields and the North East, which currently supply (and will continue to supply) most of the UK power station coal, have sulphur contents averaging 1.6 per cent, concentrated mainly within a narrow band of 1.3 per cent to 1.8 per cent. On the other hand, the UK has little very high sulphur coal with less than 3 per cent of disposals containing more than 2.5 per cent sulphur.

8. The sulphur in coal is present in two main forms, organic and pyritic. A third form, sulphate, is too small to be of concern. The split between organic and pyritic sulphur is roughly equal in most UK coals. Organic sulphur is present in the form of various sulphur–carbon complexes as part of the coal structure. It cannot be removed by any physical process. In theory it could be removed by chemical breakdown of the coal structure. A number of approaches have been investigated, particularly in the USA, but none has proceeded to commercial operation and none is expected to do so in the foreseeable future. Pyritic sulphur is dispersed in a variety of ways in coal, some of it as distinct nodules which are removed by conventional coal cleaning methods, but the greater part of the pyrites is almost always present in finely divided form and therefore cannot be economically removed during such cleaning.

9. The scope for reducing the sulphur content of UK coal as mined is extremely limited. It can be seen from Appendix 2 that the lower sulphur coals tend to be produced in the Scottish and South Wales coalfields. In principle, maximising productive capacity in those areas at the expense of the central coalfields could in the long term lead to a marginal reduction in UK average sulphur levels. However, as the Board's most recent Report and Accounts show, these areas tend to have high production costs, because of difficult geological conditions.

10. The planning of production from existing capacity can affect sulphur levels on a short term basis in cases where multiple seams with different sulphur levels are worked from one colliery. However, changes in the order in which seams are worked cannot alter the sulphur content of the accessible reserves.

11. In a few cases sulphur is distributed in a particularly non-uniform manner within a coal seam, the concentration in the lower part of the seam, for instance, being significantly higher than in the upper parts. In such a case, leaving coal in the floor of the seam on cutting would reduce the sulphur level of the product, but at the penalty of increased unit cost of production. Regardless of cost, however, few such opportunities arise where a change of mining practice can bring about noticeable changes in sulphur level.

COAL CLEANING

12. The coals sold into the household and carbonisation markets are fully washed and this applies generally also to the majority of industrial (non-electricity) coals. But nearly 70 per cent of UK coals is sold into the power station market where it is used almost exclusively in pulverised fuel (pf) units. Typical coal as prepared for this market has a top size of 50 mm or less, an average ash content of about 16 per cent and sulphur content of about 1.6 per cent. It is necessary to wash about two-thirds of the raw coal to achieve this desired ash level. Treatment of the finest fractions is very disproportionately expensive in capital and operating costs and produces major problems of effluent disposal, so minimum loss of combustible matter and minimum cost of preparation is achieved in the coal preparation process by extracting the finest fraction of the raw coal (about one third) before washing the remainder. The two fractions, washed coarse and untreated fines, are then blended together to form a handlable power station fuel (PSF). Modern coal preparation plants for power station coal are equipped with froth flotation sections for treating some of the very fine (−0.5 mm) coal. The "blended smalls" resulting from normal PSF preparation practice have a sulphur content reduced on a thermal basis by about 15 per cent to 20 per cent compared with the raw coal.

13. A further reduction in sulphur could be achieved in principle by washing the one third untreated element of PSF. In general UK coals with the highest sulphur content contain the greatest amount of inorganic pyrites, and hence are assumed to offer the greatest potential for reduction of sulphur by washing. In special examinations of coals with greater than 1.9 per cent sulphur at 24 different collieries, representing roughly 20 per cent of CEGB supplies, it has been shown that on average a sulphur reduction of eight per cent on a thermal basis would be achievable by total washing. That is, a net 25,000 tonnes per annum of sulphur (two per cent of CEGB sulphur receipts) would be removed. Extending total washing to all deepmined CEGB coals would achieve a lower average rate of removal. At most a net 55 to 60,000 tonnes per annum of sulphur (less than five per cent of CEGB sulphur receipts) might be removed.

14. The capital and operating costs of washing fine coal are approximately three times those for coarser sizes, so a substantial capital investment would be required for the addition of current proven commercial coal preparation plant to achieve this modest reduction in sulphur delivered. To provide the additional facilities needed for total washing for the 24 high sulphur coals (about 20 per cent of CEGB supplies from the NCB), this capital cost has been estimated at approximately £100m. However, actual expenditure might be very much higher because at many collieries it would not be good engineering practice to add new, modern plant to the existing plant and entire existing plants might have to be demolished and rebuilt. Taking into account operating costs, combustible losses in the process and allowing for savings on transport of the cleaner fuel to power stations we have estimated that total washing of the 24 highest sulphur deepmined coals would cost on average £850 per tonne of sulphur removed. This cost per tonne would be substantially greater if total washing were to be extended to all power station coals.

15. The "deep washing" of coal, that is recleaning totally washed coal in second stage processors to produce separate lower and higher sulphur streams, could, in principle increase the effectiveness of flue gas desulphurisation (see below) by concentrating high sulphur streams at fgd equipped stations. The additional capital cost at the 24 collieries

to provide the rewash equipment would be about £250 million, but the cost effectiveness of deep washing would depend on logistical and operational considerations which have not yet been fully examined. It is clear, however, that the consideration of deep washing can only be seen as a part of the optimisation of an fgd strategy. It cannot contribute to sulphur reduction on its own.

16. Since pyrites is finely disseminated and interbanded with coal, any further reduction in sulphur content is only possible after crushing to below 3 mm size, and preferably minus 1 mm, before additional processing. This would not only result in significantly higher costs, but would also provide an unhandlable product which would be unacceptable to power stations unless thermally dried and differently transported and stored at generating sites. There are a number of new coal cleaning processes being investigated such as chemical treatment, microbiological treatment, high gradient magnetic separation and others, but none is near commercial application stage, and all demonstrate that the potential for sulphur reduction is not available unless the coal is similarly crushed to less than 1 mm size. There is, then, in our view, no real prospect of any major breakthrough in the economics or effectiveness of coal cleaning processes in the foreseeable future. It is important to bear in mind, when faced with some of the more startling claims made for the effectiveness of coal preparation in removing sulphur, that the washability characteristics of coals from various parts of the world do vary greatly and also that the pyrite levels in UK coals are typically less than one per cent compared with perhaps five times this level in certain North American coals.

FLUE GAS DESULPHURISATION

17. The NCB has no special expertise in the field of processes to remove sulphur oxides from flue gas and does not operate any such plant. However, at the suggestion of the Advisory Committee on Research & Development (ACORD), a joint CEGC/NCB Working Group on "Sulphur in Coal" was set up in 1982 and a sub-group is making a special study of the technical and economic implications of flue gas desulphurisation in power generation. The Working Group has agreed to submit its overall report to the Department of Energy by mid-1984.

18. Many processes have been proposed for flue gas desulphurisation but only a few have been used in commercial plants. All commercial applications are based on the use of alkali to absorb the sulphur oxides. In the UK power stations at Battersea, Fulham and Bankside used the natural alkalinity of River Thames water to wash flue gas in the period between 1930–60. Waste water was returned to the Thames, and the exhaust plume was not reheated and so resulted in a low level mist. Such practices would be unacceptable today and substantial additional costs would be incurred in ensuring environmental acceptability.

19. In the US most plants use lime or ground limestone as the alkali to react with sulphur oxides. This produces a calcium sulphate/sulphite slurry that is difficult to dewater and needs to be mixed with ash, cement or soil before it can be disposed of satisfactorily. An improved version of this process can convert the sludge to gypsum which is more easily disposed of to landfill or can be used for the manufacture of products such as plasterboard.

20. Another group of processes use reagents to dissolve sulphur dioxide from flue gas and then regenerate it in a concentrated form which can be used to make sulphuric acid or sulphur. The most advanced of these processes is the Wellman Lord in which a solution of sodium sulphite is used as the reagent. This process has been installed in the US, is under consideration in Japan, and appears to be the most suitable for large installations in the UK. Ninety per cent sulphur removal is attainable. A number of published studies indicate that the capital cost of these processes is in the range £60–£130/KW. The effect on the cost of electricity generation is complex because, in addition to capital and operating costs on the scrubbers, there are also increases in the cost of operating the whole generating system if it is used to make up the loss of output resulting from the FGD plant. Published studies indicate generating cost increases of up to 15 per cent are attributable to flue gas washing.

21. Although at the time of writing the conclusions of the joint study with CEGB are yet to be agreed, in order to allow comparisons with the figures quoted above for the costs and effectiveness of coal washing we offer the following estimates. Flue gas desulphurisation (fgd) retrofitted to one base load coal-fired power station (2000MW) would have an effect rather greater than totally washing all CEGB supplies. About 70 to 90,000 tonnes per annum of sulphur would be removed (say six to seven per cent of CEGB emissions). Capital cost would be about £150 million (as compared with about £400 million for total washing of all supplies). Cost per tonne of sulphur removed would be in the order of £400. While this is substantially lower than the cost of coal washing (para 14) it nevertheless represents a significant addition to the cost of power generation.

22. Unlike coal preparation, fgd has the potential to reduce SO_2 emissions from UK power generation by amounts greater than five per cent. CEGB have estimated that retrofitting to twelve stations would be necessary to achieve a 60 per cent reduction in their SO_2 emissions.

23. There is little published information on the cost of flue gas desulphurisation for industrial plant. Cost comparisons are very sensitive to particular applications and depend on such things as size, the process used, whether new or "retrofit", sulphur content of the fuel and clean up standards. Studies have indicated that costs of desulphurisation for small plants of about 50 MW thermal are some four to five times greater than for large plants associated with major power generation units. In the US packaged units using caustic soda as the absorbant have been used on industrial boilers but liquid waste disposal problems are severe and the process is only economic in particular circumstances where a high sulphur coal is available at a very low price.

SULPHUR REMOVAL DURING COMBUSTION

24. Flue gas desulphurisation is the only effective choice for significant reductions of SO_2 from existing power stations. However, advanced systems are under development which would enable a new generation of coal fired stations to suppress SO_2 whilst avoiding the efficiency penalties associated with fgd. One of these, combined cycle gasification, will require the development of a new generation of high temperature gas turbines, although ultimately it could be economically the most attractive technology. Nearer to commercial scale availability is pressurised fluidised bed combustion (PFBC) technology. The nature of the fluidised bed combustion process allows sulphur to be captured by limestone in the bed at the combustion stage. NO_x emissions are also lower than in conventional pf combustion. By combining a steam turbine driven from in-bed water tubes and a gas turbine driven by the cleaned exhaust gases, PFBC offers the prospect of high efficiency power generation combined with enhanced environmental acceptability. American studies indicate potential generating cost advantages in the order of 13 per cent compared with new conventional plant fitted with fgd.

25. UK studies of PFBC sponsored by ACORD and carried out jointly by the Board and CEGB are underway. The technology is at the stage of large scale experimental evaluation. A major programme of experimental work under International Energy Agency auspices is nearing completion at the Grimethorpe facility in Yorkshire. In order to translate this to commercial application it will be necessary to carry out further work on the performance and reliability of individual components to provide design data for a commercial scale demonstration plant, and to involve British gas turbine manufacturers and boiler makers at appropriate stages. The Board and CEGB are considering such a pilot plant programme, which is seen as the first stage of a UK programme culminating in the commercial availability of a new, more efficient and environmentally acceptable power generation technology.

NO_x SUPPRESSION

26. The average nitrogen content of UK coal is about 1.5 per cent. The nitrogen is an organic part of the coal substance and cannot be removed by coal cleaning. In the combustion of coal, NO_x results both from the oxidation of some of the nitrogen in the

fuel and also of nitrogen in the combustion air. The main factors influencing the rate of NO_x formation are combustion temperature, the availability of oxygen, residence time in these conditions and fuel nitrogen content. Multi-stage burners are being developed for use in pf units which mix the air and fuel in a controlled manner in order to avoid conditions of high excess oxygen and high temperature. Such burners can be applied, however, only where furnace design can accommodate the resulting increased flame length. We understand that CEGB are working at present to establish the extent to which retrofitting of such burners is possible in existing units and the extent to which this would enable NO_x emissions to be reduced.

27. There are really no practicable means of reducing the NO_x emissions of grate or stoker-fired units, used extensively in the industrial coal burning sector. However, NO_x emissions from these types of device are distinctly lower per tonne of coal burnt than they are from pf fired units because of the lower combustion temperatures and the staged combustion conditions resulting from the thickness of the fuel bed. Nevertheless, there must be some doubt whether the NO_x emission limits called for in the draft European directive on emissions from large combustion plant (see below) can in fact be met.

THE PROPOSALS OF THE EUROPEAN COMMISSION

28. The European Commission has proposed a variety of measures in the field of air pollution. The Commission's declared approach, set out in its "communication concerning environmental policy in the field of combatting air pollution" (COM(83)721), notes the need to understand better the relationships between emissions and observed environmental problems. It is disappointing to see, then, that this need has apparently been largely ignored in some of the proposals the Commission has put forward. Perhaps this is best exemplified by the "explanatory memorandum" to the proposed directive on emissions from large combustion plant (COM(83)704). The Commission supports the measures it proposes by a logic which implies far more than is known or can reasonably be assumed from available data. There is a lack of balance in the way the Commission quotes from the report on the subject of acid rain prepared for it by Environmental Resources Ltd. For instance, in our view, the report's findings on estimated costs and benefits are not accurately presented. There appears to be a similar imbalance in the reporting of the Commission's September 1983 symposium in Karlsruhe on "Acid Deposition—A Challenge for Europe" which is quoted as having concluded that considerable reductions in SO_2 and NO_x emissions should be brought about as soon as possible. The NCB delegate at this symposium, however, noted that the concluding speeches of the politicians and administrators did not reflect the more cautious and less alarmist tenor of the scientific debate which had taken place.

29. COM(83)721 also indicates recognition of the need to integrate protection of the environment with the development of policy on energy, industry, transport etc. Unfortunately here too there is little evidence in the Commission's proposals that the effects on energy costs to industry and on the Community's policy on the use of coal have been fully considered.

30. Community legislation already exists relating to ambient air quality. Limit and guide values for SO_2 and suspended particulates are in force. The Council recently agreed an important new directive on "combatting air pollution from industrial plants" (draft COM(83)173) which broadly seeks to harmonise procedures for plant approvals on linds which appear similar to the "best practicable means" approach of the UK's Industrial Air Pollution Inspectorate. But it also establishes the principle of Community-wide emission limits for specific types of plant. There is perhaps an inconsistency between the two approaches and the danger exists of inappropriate use of Community-wide emission limits in the energy sector. The application of "best practicable means" in countries whose energy economy is founded on different resource bases is unlikely to lead to the same emission levels throughout the Community. A fixed emission limit will then either be unachievable (except at unreasonable cost) in some member states, or less than the best practicable in others. The two approaches are incompatible. The Board considers that the "best practicable means approach" as applied for many years in the UK by the Industrial Air Pollution Inspectorate, with its flexibility to take account of specific circumstances, is

the most effective and equitable way of ensuring a balance between environmental ideals and industrial activity. Community-wide emission limits applied in the energy sector could well introduce distortions which would militate against the Community ideal of equal competition.

31. Of the various pieces of draft European legislation under discussion perhaps that with the greatest potential for economic impact is the large combustion plant directive, COM(83)704 final, already mentioned, which appears to be based very much on the measures introduced in Germany in 1983. It introduces two concepts: specific emission limits for SO_2, NO_x and particulates for individual new plant over 50MW(th), and overall emission reductions for each of these "pollutants" from the totality of plant over 50MW(th) in each member state by 1995, the so-called "bubble concept".

32. One difficulty with fixed emission limits has already been discussed. But there is no doubt that the proposed limits would require all new coal or oil fired power generating plant either to be fitted with flue gas desulphurisation or to be based on some advanced technology such as pressurised fluidised bed combustion. However, for the UK it is particularly worth looking at the possible effect of the proposed limits in the "medium size plant" sector of 50 to 300MW(th). This would be below the size of most power generation plant in UK but coincides with a significant sector of industrial plant, mostly for steam generation. The proposed SO_2 emission limit of 2,000 mg/m^3 for this size of plant could be met by the direct use of coal with a sulphur content of consistently less than about one per cent. As shown earlier, such fuel is only available in very limited quantities from UK sources. The availability of low sulphur coal on the world market, from for instance Australia or South Africa, is greater. Undoubtedly such "compliance coal" would soon command a significant premium in Europe if such legislation were to be introduced. The effect of the proposal, then, on industrial plant would be to increase the demand for low sulphur, predominantly imported, coal; to increase demand for gas as an industrial fuel; and to discourage industry from investing in new boiler plant since existing plant would not be directly affected by the proposals. All of these would increase the energy costs of industry and the last could have quite the opposite effect to that desired. The alternative of flue gas desulphurisation on industrial plant, which with any coal or oil could easily meet the proposed limit, would be enormously expensive for this size of plant, as discussed earlier at para 23.

33. One other anomaly in this draft is that the higher emission limit (2,000 mg/m^3) proposed for medium size plant (50–300 MW(th)) does not apply to fluidised bed units which instead would have to comply with the much more severe 400 mg/m^3 SO_2 limit. With UK coals this implies a retention of sulphur of 80 to 90 per cent. While this sort of retention may be possible in some cases with the deep beds developed in other countries, the shallow bed technology developed for the industrial market in the UK could not be expected to achieve such a degree of retention. It is possible, then, that the effect would be to discourage the adoption of a potentially less polluting technology.

34. The fundamental objective of the draft directive 704 lies in the second concept, the overall emission reductions from each Member State (which are assumed by the Commission to lead to the various environmental benefits described in its "explanatory memorandum"). This concept is not without its difficulties (see below) but if such reductions are to be achieved in the proposed timescale then the emission limits specified for individual new plant are at best an irrelevance. If such reductions are required then more thought needs to be given to the most cost-effective means of achieving them. The answers will not necessarily be the same in each Member State, but since the local effects of emissions are already controlled by existing (UK and European) legislation, and any longer-range effects cannot be source-specific, we consider the proposal of Community-wide emission limits for individual plants as part of COM(83)704 to be inappropriate.

35. Various difficulties can be anticipated in applying the concept of overall emission reductions by Member States. The two most obvious are the problem of agreeing the base number in each case (emissions from "relevant plant" in 1980), and the argument that using 1980 as a base year could disadvantage those member states (such as the UK) who,

for various reasons, may have significantly reduced their SO_2 emissions over a period prior to that date. Such problems, would perhaps not be insuperable. More important, however, is that any effects of emission reduction by EEC countries will be vastly diluted in some member states by continuing emissions from non-EEC sources, notably East Germany and USSR.

36. The proposal also includes emission limits and reduction targets for particulates. It is not clear at all why a directive said to be aimed at acid deposition should require this.

37. Of the other Commission initiatives in various stages of development, perhaps that of the greatest concern to the Board is the possibility of a proposal to limit the sulphur content of fuels. The Commission made such a proposal, to apply to fuel oil only, in 1975. It was eventually withdrawn because of objections from member states, particularly objections that it did not apply to coal. The Commission's policy document COM(83)721 refers to reviving an extended version of this proposal and in view of the previous objections the revision could well be expected to apply to coal. Without knowing the sulphur level to be proposed, it can be inferred from the earlier fuel oil proposal that it is likely to be at a level which cannot be satisfied by the bulk of UK coals whatever type of cleaning they may have undergone. The 1975 proposal called initially for two per cent sulphur fuel oil falling later to one per cent. Because of the difference in heat content, this is equivalent to coal of about 1.2 per cent and then 0.6 per cent sulphur content. Perhaps 25 per cent of UK coal satisfies the first criterion, and less than one per cent satisfies the second. It is hard to see how such a proposal could be compatible with or a necessary complement to the Commission's other proposals for overall emission reductions and for emission limits. It would also clearly be contrary to the Community policy of encouraging the use of indigenous coal (in that a major part of the Community's coal industry, and hence its energy resources, could effectively be wiped out).

THE FINANCING OF POLLUTION CONTROLS

38. When the form and extent of further pollution controls are unknown it is clearly not possible to comment in detail on appropriate methods of financing. Any economic case which may be presented on the need for further controls is not, or should not be, fundamentally dependent on how the resultant costs are distributed. In that sense, the question of financing is a secondary one. Moreover, we have shown that no action that the Board can take can contribute directly to a significant reduction of SO_2 or NO_x emissions from coal combustion. In these circumstances, although its views on the subject have been invited, the Board prefers to confine itself to the following general observations.

39. We have argued (para 33) that, if expensive controls are necessary, then they should be of a form which allows each nation to decide on its most cost-effective course of action to achieve its (internationally agreed) overall targets. This could result in one sector, for instance power generation, being called upon to achieve the whole of the national reduction. In that case some form of "adjusting mechanism" might be called for to avoid a disproportionate burden falling on the electricity consumer. In our view, the difficulties in deciding upon and implementing such a mechanism should not be allowed to override the need for overall objectives to be met in the most cost-effective manner.

RESEARCH CARRIED OUT BY THE BOARD

40. The total cost of research and development related to controlling emissions from coal-fired plant carried out by the Board since 1967 is some £135 million (at current prices) of which £100 million was from external sources, mainly USA and Germany. This expenditure, together with that planned for future years, is set out in Appendix 3. The most important projects are discussed below.

41. *Atmospheric fluidised bed combustion* (*AFBC*): One of the advantages of burning coal in a fluidised bed is that sulphur can be retained by the addition of limestone or dolomite. Fluidised combustion can be carried out at atmospheric pressure (AFBC) or at elevated pressure (PFBC). Research into AFBC with limestone addition has been per-

formed by the NCB since the 1960s at its Coal Research Establishment (CRE), Cheltenham and at the Coal Utilisation Research Laboratory (CURL) at Leatherhead. Shallow bed AFBC technology has been developed for the industrial boiler market and its sulphur retention characteristics have been evaluated. The results from this work indicated that at a calcium : sulphur molar ratio of about 3 : 1, sulphur retention in the bed of around 65 per cent could be achieved.

42. *Pressurised fluidised bed combustion (PFBC)*: For power generation applications, additional economic advantages arise from operating the combustor bed at pressures of 5–20 bar. This enables the gases to be expanded through gas turbines, as well as being used to raise steam for steam turbines and results in an increase in the overall efficiency of power generation equivalent to a reduction in fuel consumption of about five per cent. A further advantage of pressurised operation is that formation of nitrogen oxides is inhibited, and this in turn reduces atmospheric emissions. Typically NO_x levels are about 40 per cent of those expected from conventional pf firing.

43. The NCB has been involved in research and development on PFBC since its inception in the 1960s. The small scale research has been carried out at the CURL laboratories in Leatherhead, and these facilities will be moved to the CRE laboratories as part of a reorganisation during 1984. The NCB also acted as operating agent for the larger scale test facility at Grimethorpe. This programme was sponsored jointly by the governments of the UK, USA and FRG under the auspices of the International Energy Agency. Tests at Grimethorpe have shown that for a high load operating condition 90 per cent of sulphur can be retained. The IEA project will finish during 1984 and the Board will then acquire the facilities at Grimethorpe. The NCB and CEGB are considering a further programme of work, lasting two years and costing £25 million.

44. The environmental impact of the disposal of the solid residues from PFBC is being assessed at the CRE under a part ECSC funded project. Ways of utilising the residues are also being investigated.

45. *Fluidised Bed Gasification*: In common with FBC, fluidised bed gasification offers the capability of sulphur retention by the addition of limestone or dolomite to the bed. The Board has been active in this area since 1974. At atmospheric pressure, similar sulphur retention capabilities have been observed for both limestone and dolomite: a 2 : 1 calcium: sulphur molar ratio resulting in approximately 90 per cent sulphur retention. Preliminary measurements have shown that the formation of NO_x precursors is low. Current studies, supported by the ECSC and the EEC, are aimed at the production of an industrial fuel gas.

46. *Power Generation Studies*: Two engineering design studies have been commissioned to look at the technical and economic feasibility of PFBC and Gasification/Combined Cycle for reducing sulphur emissions from power stations. Each study will last for about two years and is being contracted to private industry. The PFBC study will draw on experience gained at Grimethorpe and is being supported by the NCB, the CEGB and the UK Department of Energy. The Gasification study will be based on BGC's experience at Westfield and is being supported by the NCB, the CEGB, the BGC and the UK Dept. of Energy.

47. *Royal Society Study on Acidification*: the NCB and the CEGB have each agreed to contribute £2.5 million to a five year study on acidification. This work is being organised by the British Royal Society in collaboration with the Swedish and Norwegian Academies. The remit of this study is to establish factors which influence acidification. Research programmes are currently being agreed by the Royal Society. Contracts will be placed and experimental work started during 1984.

48. *Loch Fleet Project*: Some lakes in southwest Scotland have shown increased acidity over recent decades. The NCB has provisionally agreed to participate with CEGB and the Scottish electricity boards in a project at Loch Fleet to study the effect of the local flora and the modification of the water chemistry of the loch by treatment of the catchment area and directly of the loch water. The estimated cost over five years is £600,000.

SUMMARY OF THE MAIN POINTS OF NCB EVIDENCE

49. Much is still unknown about the links which may exist between emissions from fossil fuel combustion and observed environmental damage. Decision on environmental action must always be based on the best available data and must take account of cost effectiveness. (Paras 4–6).

50. The scope for sulphur removal through coal washing is extremely limited. Total washing of all power station fuel would, at maximum, be rather less than equivalent to retrofitting of flue gas desulphurisation to one 2,000 MW power station and would be less cost-effective. (Paras 12–14 and 21).

51. Large reductions in UK SO_2 emissions (such as the Commission's proposal of 60 per cent) by 1995 could only be achieved by retro-fitting of fgd to existing base-load power stations. (Para 22).

52. The legislative approach of the European Commission, besides being based on somewhat arbitrary assumptions about cause and effect, is not self-consistent. Community wide emission limits are not compatible either with a "best practicable means" approach or with the cost-effective implementation of the "bubble concept" of overall emission reductions, and moreover could lead to distortions of competition within the Community. Any decisions on environmental matters must take account of social and economic consequences. (Paras 28–34).

53. We favour retention of the "best practicable means" approach to air pollution matters. If the convincing balance of evidence showed that reductions in emissions would result in significant net environmental benefit, and that no alternative or more selective approach could achieve substantially the same ends more cost-effectively, then we would favour the achievement of such reductions by the "bubble concept" of overall emission reductions, leaving each country to choose for itself the most cost-effective way of achieving such reduction in the light of its own circumstances (in terms of resources, industrial structure etc). (Paras 30, 34 and 35).

54. The National Coal Board is conscious of its environmental responsibilities and continues to undertake substantial research aimed at controlling emissions from coal-fired plant, and to implement developments based on that research. (Paras 2, 40–48).

April 1984

APPENDIX 1

RECENT EVIDENCE INFLUENCING NCB POLICY ON ACID RAIN

In 1983, the available evidence on Acid Rain was assembled by Environmental Resources Limited for the Commission of the European Communities, the report being issued in September 1983. The report covers the principal issues associated with acidic emissions and deposition in the EEC and Europe and considers the apparent effects to trees, crops, aquatic ecosystems, buildings and health. The report notes that the main impetus behind the issue of late has been the forest damage in the FRG. This has been attributed to the acidification of soil resulting in root loss and damage to foliage by gaseous pollutants, especially in the summer when ozone levels are highest. Although these may be contributory factors, the report states that in the FRG, poor soils, high altitude, a predominance of old trees and modern forestry management techniques are also implicated. The report concluded that the critical issue of the relationship between pollutant emissions and acidification was far from sufficiently well understood.

Subsequently, further evidence has become available. The Karlsruhe Symposium on "Acid deposition—a challenge for Europe", held in September 1983 and organised by the Commission of the European Communities, aimed to assess some of the scientific, technical and economic aspects associated with acid deposition. The NCB delegate at this symposium noted that the representations by some politicians and administrators assumed (a) that acid deposition had been proved to cause extensive harm to forests, fisheries and soil, (b) that the problem was one of great urgency and (c) that a drastic reduction in SO_2 and NO_x emissions in the short term was essential to avoid rapid deterioration in the environment. In contrast the scientists presented a less alarmist viewpoint agreeing that the problems are not being caused by just "acid rain" but that dry deposition and the effects of gaseous pollutants constitute an important contribution to the environmental effects.

Ozone is now regarded as of at least equal importance to sulphur and nitrogen oxides in the chain of events leading to ecological damage. *Ulrich* claimed to have firm evidence of soil acidification, with loss of calcium and magnesium and release of toxic metals including aluminium, in German forest soils but subsequently other workers (eg *Rehfuess*, 1983) have refuted this. Several speakers at the Symposium referred to the self-acidifying action of coniferous forests, and of modern forestry practices. The NCB delegate concluded that, on the presented scientific evidence, there are many questions still to be answered especially on the long term effects of acid deposition on different soil types.

Binns (50th National Society for Clean Air Conference 1983) reported on the "Ecological effects of acid rain on forest and soils". He stated that there was no evidence of direct damage by acid rain to trees although he recognised that extensive damage had occurred in forests, particularly in the FRG. In his opinion the exact causes are unclear. He said that it was difficult to attribute the recent damage in Germany solely to sulphur dioxide as emissions of this pollutant have been diminishing since the 1970s. Moreover affected forests have appreciable lichen populations, which are sensitive to SO_2. A more plausible explanation is the combined effects of ozone and acid mists with climatic stress arising from the extreme drought of 1976 being another possible factor. Overall Binns' view is in agreement with the findings of the Environmental Resources Report.

At the same conference *Kinsman* spoke on "Acid Rain: ecological effects on watercourses and fish". He said that events (short peak values) affected the freshwater environment and that there is often a local variation in the acidity of streams, the reason for which is unknown. During the Esk troutkill at the end of the 1983 drought, H^+ concentration changed by greater than one order of magnitude but this was not related to the acidity of the rain that fell. Moreover over a season pH levels in lakes can change by as much as 3 pH units due to biological activity (eg photosynthesis). Reduction in water pH levels generally results in a loss of numbers of species but pH alone is not the only factor involved; loss of ionic strength can prevent uptake of vital elements such as sodium. In this situation fish would die from sodium stress irrespective of the acidity.

Kinsman stated that accurate pH measurement was extremely difficult and that ±100 per cent on H^+ concentration was about the best that could be achieved. This factor alone indicates the uncertainty in claimed values of decreasing lake pHs that have been reported. In conclusion Kinsman said that until the causative factors of aquatic acidification are better understood, the application of control, preventive or ameliorative measures will be a high-risk activity.

In December 1983 the Watt Committee on Energy reported the preliminary findings of their working group on acid rain. Their conclusions were in accord with both those of the Environmental Resources Report and the views given by Binns and Kinsman to the NSCA, namely that the relationship between sulphur and nitrogen oxides emissions and acidification is still far from understood, and that the scope for the reversibility of alleged acidification damage is unclear.

APPENDIX 2

SULPHUR CONTENT OF UK COAL 1982/83

Area	Saleable Output (million tonnes)	Average Sulphur Content as received (%)	thermal basi (g/GJ)
Scottish	6.6	0.70	300
North East	12.4	1.49	570
North Yorks	8.4	1.92	780
Doncaster	6.8	1.48	590
Barnsley	8.1	1.85	730
South Yorks	7.3	1.59	600
North Derbyshire	8.1	1.69	690
North Notts	12.4	1.48	590
South Notts	8.3	1.37	570
South Midlands	8.2	1.56	640
Western	10.8	1.52	590
South Wales	6.9	0.95	340
Scottish Opencast	2.8	0.95	390
NE Opencast	3.1	1.56	560
NW Opencast	1.0	2.34	860
Central W Opencast	2.5	2.07	870
Central E Opencast	3.2	1.96	790
SW Opencast	2.1	0.90	290
Great Britain	119.0	1.51	590

APPENDIX 3

Summary of Research Undertaken by the NCB Related to Controlling Emissions from Coal-Fired Plant

Topic	Period	Total cost £m*	Cost to NCB £m*
1. *Fluidised Bed Combustion Atmospheric Pressure*			
(a) Deep bed technology (principally for power generation)	1967–72	10	8†
(b) Shallow bed technology (principally for industry)	1973–date	0.5	0.6
Elevated Pressure			
(a) R & D at CURL	1967–date	20	0
(b) Operations at Grimethorpe	1975–date	94.3	19.94‡
2. *Fluidised Bed Gasification*			
(a) Technology for power generation (ECSC part funded)	1974–date	7	2.8
(b) Technology for industry	1981–date	2	1
3. *Utilisation and disposal of FB residues.* (Part ECSC funded)	1982–date	0.26	0.1

* Present day cost equivalent.

† Remainder funded by the Environmental Protection Agency of the USA.

‡ Total—cash and steam (at commercial rates). (Cash—£4.27m, steam—£15.67m).

Summary of Research Planned by the NCB Related to Controlling Emissions from Coal-Fired Plant

Topic	Period	Total cost £m*	Cost to NCB £m*
1. *Fluidised Bed Combustion Atmospheric Pressure*			
Technology for Industry (Proposed ECSC project on SOX, NOX, hydrocarbon emissions)	1985–7	0.2	0.08
Elevated Pressure			
R & D at CRE	1984–	1 pa	1 pa
Proposed Operations at Grimethorpe	1985–7	25	12.5
2. *Fluidised Bed Gasification*			
Technology for Industry	1984–	1 pa	0.5 pa
3. *Department of Energy Studies*			
(a) PFBC	1984–5	0.5	0.126
(b) Gasification/CC	1984–5	0.5	0
4. *Royal Society Study on Acidification*	1984–9	5	2.5
5. *Continuing—Utilisation and Disposal of FB Residues (ECSC)*	1982–6	0.26	0.1
6. *Loch Fleet Project*	1984–9	0.6	0.2
7. *MRDE Work on Sulphur Reduction in Coal*	1984–	0.2 pa	0.2 pa

* Present day cost equivalent.

Examination of Witnesses

MR I K MACGREGOR, Chairman, MR M J EDWARDS, Market Director, DR A D DAINTON, Director, Coal Research Establishment, and MR R W C WHEATLEY, Director of Scientific Control, National Coal Board, called in and examined.

Chairman

598. Mr MacGregor, may I first of all thank you and also your colleagues for coming here and spending your time with us this afternoon. I realise that you have other matters to preoccupy you at the moment and, therefore, your presence is doubly appreciated. May I say thank you also for your paper which has been submitted, the written evidence, which is extremely helpful. In its introduction you say that the National Coal Board has not carried out any significant work on the relationship between emissions, acid deposition and observed damage to forest and water ecology but you rely upon published data for your information. As we have access to these data and we have received a great deal of direct evidence ourselves from scientists engaged in research in these fields I do not think we need trouble you too much about that aspect of the matter. Instead I would like to concentrate on the options available for the reduction of SO_2 and NO_x emissions, their cost-effectiveness and also the EEC draft regulations about which, in fact, most of your paper is concerned, and if we have time later on to come back to the other matters then perhaps we can touch on them briefly. This brings me at once to paragraphs 12 to 16 of your paper, which are concerned with coal cleaning. As I understand the stated position, all coal sold, certainly that for use within the United Kingdom, is fully washed except for approximately one-third of that which is used for electricity generation because this one-third is too fine a dust to enable it to be washed economically. Therefore, I would like to ask this: the coal which is subject to this washing process, how much sulphur is left in the coal after it has been washed?

*(*Mr *MacGregor.)* Mr Chairman, the amount of sulphur varies over a very wide spectrum because of the occurrence of sulphur in the coal. As you know, most of the coals in the United Kingdom come in the one-and-a-quarter to one-and-three-quarters category, a small percentage of our reserves being less than one per cent. With regard to the bulk of the coal that we mine for power station purposes and industrial purposes, I would say that the average is somewhere between one and one-quarter and one and three-quarters and in the case of these coals about half of the sulphur is present in organic form in combination with various compounds in the coal. The orthodox washing process is an attempt to deal with the inorganic sulphur which is in combination with generally iron as iron sulphide or iron pyrites and, therefore, we have some chance to release that from the mixture and eliminate it because of its different density. Most of the washing systems are based on density differentials. As I see it, we have reached a point of, shall I say, reasonable economic balance in respect of the current understandings as regards the problems of sulphur. I would like to ask Dr Dainton, who is a scientist who has spent a great deal of his time, together with Mr Wheatley, on the subject, to give you some further views on the occurrence of sulphur and on the mechanisms that are used for eliminating it by washing. I would like to summarise by saying that all our studies would seem to indicate that the elimination of sulphur compounds from coal by methods which could be regarded as reasonably manageable economically end up with a fairly poor return on the capital investment; in other words, they are not cost-effective. Perhaps Dr Dainton or Mr Wheatley would like to talk on this.

*(*Mr *Wheatley.)* Chairman, as Mr MacGregor has said, the average sulphur content of British coals is round about 1.5 to 1.6 and in respect to your specific question about how much sulphur is removed in the present washing, we probably remove about 15 per cent of the sulphur. It does not change significantly the average sulphur in percentage terms. You have to relate it to the thermal content.

599. Is that because British coal has a high degree of organic sulphur within it?

*(*Mr *Wheatley.)* No, it is certainly because round about half is organic, but what I am really trying to say—and it is not easy to put the figure across—is that it is because we have a situation where, unlike some of the American coals, which have very high pyritic sulphurs, ours is about 50/50. What I am saying is, for example, in the work we have been doing where we have simulated the washing of the remaining one-third the

[Chairman *Contd.*]

sulphur as a percentage has remained unchanged, although we are saying this would be reduced in terms of sulphur emitted per therm of coal burnt. There would be a reduction of somewhere around six per cent or eight per cent with the higher-sulphur coals, so this would fit in with my figure. All I am saying is where we wash the two-thirds, the reduction is about 15 per cent compared with the sulphur in the run of mine. That is the first point, but on the work we have done in washing these coals what we have been faced with is that if we concentrated on the high-sulphur coals—and we have chosen that at the level of 1.9 per cent sulphur or above—we would reduce the sulphur in terms of tonnage in the supplies going to the CEGB from our mines by 25,000 tonnes or about two per cent of the sulphur which the CEGB is emitting at the moment. If we were to wash all our power station coals we would make a reduction of about 4½ per cent in the CEGB's sulphur deliveries but this would be at a cost of round about £90m per annum, that is, after we have taken account of the capital we would have to invest—these costs are almost certainly minimum figures—whereas of the coal at a single power station which was equipped with FGD (flue gas desulphurisation) we would estimate they would remove 80,000 tonnes of sulphur, about 6½ per cent of their emissions. We estimate that the cost of doing this would be comparable with the net cost to the country of washing the high-sulphur coals; in other words, there would be three times the reduction in the emissions without the same investment of annual cost as would be the case if we washed our high-sulphur coals in their entirety.

600. On the CEGB point, is it right that the newest power stations are using more unwashed coal than the older ones?

*(*Mr *Wheatley.)* If we are talking about very old stations which are probably now superannuated—those that have been closed—at one time in the old days the old stations were using washed more but now I would say the average ash content supplied to the base load stations up and down the country is broadly the same.

601. Can you tell me how much difference there is in the tonnes of sulphur per annum admitted into the atmosphere if one makes a comparison or tries to make a comparison between washed and unwashed coal?

*(*Mr *Wheatley.)* We do not sell unwashed at all*. Is the comparison between what it would be if we were to wash all the coals going to the CEGB compared with partly washed only? It is a blend of washed and untreated.

602. I am taking it on this basis, that the coal that is unwashed has a certain percentage of sulphur within it and when that is burnt and combusted so much sulphur will be admitted into the atmosphere. The other coal which is washed has some of the sulphur removed from it. I am still not clear how much of the sulphur is removed. Some of the sulphur is removed and what I am asking is what amount of sulphur is emitted into the atmosphere from that washed coal?

*(*Mr *Wheatley.)* The figure for CEGB emissions is 1¼ m tonnes and we are saying if we were to wash all the power station coals we would remove something of the order of 56,000 tonnes from it.

603. You say in your evidence that to have a complete wash would cost you about £100m. Is that because the plants at the 24 collieries you refer to in your paper would all have to be adapted? Is that the total cost, £100m, for 24 plants, or is it some other figure?

*(*Mr *Wheatley.)* The 24 pits refers to the high-sulphur coals only and there what we have looked at is the minimum cost if we were spending only money to upgrade the plants so that they could handle the balance of the coal which is not being washed; in other words, at some of the collieries the expenditure is minimal. In practice we believe the expenditure will be greater because it would be a question of putting new wine into old bottles. In practice I am sure we would spend more money than we indicated there but we tried to be as conservative in the estimating as we could.

604. Well, then, instead of going through the exercise of adapting to varying degrees, 24 or whatever the figure is, collieries, would it be possible to have the washing done at the point of arrival—namely, at the power stations? Would you then have a lesser number of washing plants or not, or would there be transport problems?

*(*Mr *Wheatley.)* That area we are looking at, Chairman, but perhaps there is a possi-

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* *Note by Witness:* Only a small proportion of our deepmined coal is sold unwashed.

[Chairman *Contd.*]

bility that one of the problems about removing sulphur is that half of it cannot be touched, that is, the organic sulphur, but with the otner half, the only thing is that only a proportion of it is capable of being removed by present methods of washing, because it is such a finely divided state that it cannot be separated, so one possibility is to say that if we were to finely crush the coal, we would liberate more of the pyrites and this is a possibility we are working on with our CEGB colleagues to see whether such techniques at the power station would be more practicable, for example, using a high gradient magnetic separation technique, but the problem again here, Chairman, is that if you are dealing with that sort of situation, you have got the risk of combustible losses which could add significantly to the cost, and you could have certain problems after the milling, where you could have possible explosions, although this is an area in which I would not set myself up as an expert, but it is really more appropriate for the CEGB. We are, however, certainly looking at this as a possibility.

Mr Chapman

605. In your paper there are statistics which we will consider very carefully, but you have mentioned that the coal sulphur content of UK coal is roughly 1.5 to 1.6 and there is very little high sulphur content coal. Now, in all the statistics you have given us, if the question was put to you that you were to wash all the coal that you mine in the practicable way that you can, how much would it add to the average cost of deep mined British coal, assuming I think it is about £46 a ton on average. Could you try and give us that statistic? Perhaps it is too simple to ask the question but that would give us a barometer from which to judge the issue.

(Mr *Wheatley.)* I think the best answer I can give to that is that if we were to wash all the coal the probable increase would be spread over the full 75 million tonnes which is taken by the CEGB. The effect of that would be of the order of about 1.80 pounds a ton but there might be benefits to the CEGB in the lower ash coal. I think, however, it is important to say, because that may sound a small number, that only 56,000 tonnes of sulphur, or perhaps 4½ per cent of total CEGB emissions, would be removed. I think it is doing very little in relation to the reductions they are talking about. This is why, although the figure of 1.80 pounds or perhaps less, if you allow for benefits, is there, it does need to be taken into context of the amount of sulphur you would be removing for that, which I would say is small.

606. I am grateful for that, and I suppose that is in line with the point you make in paragraph 11, and I quote, "the total washing of the 24 high sulphur deep-mined coals would cost on average £850 per ton of sulphur removed," and the sulphur is approximately 1.5 to 1.6. You mention that it would cost an additional, in theory, £1.80 per ton on an average price of £46, and yet it would only remove about 4½ per cent. I understand all that. Should not that be put in context: the enormous variation in the price of mining your coal, which I understand even in the most economic pits is of the order of £28 per ton but in the most uneconomic pits I think might well be about £80 plus per ton—would you like to comment on that?

(Mr *Wheatley.)* I am sorry, do you mean in the sense we are talking about does £1.80 make any difference?

607. I do not want to lead you into making a statement. What I am really saying is the cost of washing the coal that you deliver to the CEGB, the cost of washing it, is as nothing to the cost you would save if you were to close down a few of your most uneconomic pits.

(Mr *MacGregor.)* It is true, but it is still not a cost effective solution.

(Mr *Edwards.)* Could I just butt in here, and say that it so happens, and it is just the luck of the draw, that the lowest cost coal we produce, deep mined, tends to have sulphurs of around 1.5—that the high cost coal you are referring to, the £60–£80 per ton, tends to have the lowest sulphurs. That is just coincidence.

(Mr *MacGregor.)* It comes from places like Wales and Scotland. Let's summarise by saying that none of our studies, and this is a cost effective solution to the problem, would get sulphur down.

Mr Taylor

608. It was Mr Wheatley's evidence I think that told us and confirmed to us this very interesting point that investment in cleansing emissions after burn is three times as effective as washing the coal input in terms of ultimate reduction of SO_2 into the atmosphere. I got you right on that, did I?

(Mr *MacGregor.)* Yes.

[Mr Taylor *Contd.*]

609. That being so, and if you want notice of this question, I do not mind at all, it is scarcely the sort of statistic that most people would carry in their heads, I am interested to know if we vary the investment X—which we call a single level of investment in either washing or emission cleansing—and at point X it is three times more efficient to deal with the emission, and if X varies, does that relationship still stay linear—in other words, three times or is that an unreal question in that there is only one sensible action anyway which is enough money to get it right?

(Mr *MacGregor.*) I think the latter is the right answer.

(Mr *Wheatley.*) Could I just add this: what I think I am also saying is that as far as coal cleaning on our present state of knowledge is concerned, we are saying we can only remove 56,000 tonnes of sulphur by coal cleaning. Obviously, if you go into the FGD and then one more station you will remove more. I am saying that one station will remove about 80,000 tonnes of sulphur, but you could go to a second station. In that case we could not meet the second tranche. We will have put all our investment into removing the first 56,000 tonnes.

(Mr *Edwards.*) I think it is fair to say that if we spent £180 million we would not remove 112,000 tonnes of sulphur. It is not physically possible.

(Mr *MacGregor.*) We have reached a peak in the figures we have given you. No amount of additional investment in coal cleaning seems to yield any improvement in the sulphur. Let's put it this way: the curve has peaked out at the level we have given you and it was almost asymptotic thereon. If you are looking for a linear relationship this is it.

Mr Taylor: I would also like to ask, either now or later, whether given that we have reached a realistic limit for washing the input coal, what goes on to the performance graph in the cleansing of emissions?

Chairman

610. Can we come on to that in a moment? In the next part of the paper, we come to flue gas de-sulphurisation and then also removal during combustion by different kinds of technology. Could we just finish the coal cleaning episode first of all? The Committee has just had the advantage of a visit to Sweden, and I am sure Mr McGregor, you and your colleagues are familiar with the Swedish Coal Health Environment project. Their report was published in April of last year, 1983, and in it which may be of interest to Mr Edwards in particular the Swedes are talking very much of moving over from oil fired burning of their district heating and their power stations and the rest of it to coal.

(Mr *Edwards.*) We have got the first major project for British coal—that is, when we are producing British coal.

611. What they say here is that they are more interested in the countries that can supply them with coal of which the sulphur content is 0.8 per cent or less.

(Mr *MacGregor.*) That pretty well rules us out.

612. That is why I was asking you a lot of questions about washing and I was going to ask whether there was any relation to it?

(Mr *MacGregor.*) I have talked to the Minister out there, and I guess she has been advised by some people technically on this subject, and she has got a bug on this particular area because no amount of discussion and scientific considerations seemed to make any impression. She seems to be perfectly happy that she can go round the world and buy 0.8 per cent sulphur coal. Unfortunately that does not include ours.

613. They have got a shopping list in another book too that they have called Acidification Today and Tomorrow and we are out of the shopping list in both their publications, except that we did notice that one of the coal districts heating places we visited had very finely ground coal which is injected and mixed with lime and they are very anxious but we will come to that in a moment.

(Mr *MacGregor.*) That is part of the combustion technique.

(Mr. *Edwards.*) They have decided to put FGD on one of the projects and they will buy our coal.

614. As you say—if we can supply it.

(Mr *Edwards.*) Yes, we have a slightly temporary problem at the moment.

615. We sympathise! Can we now go to the next part of your paper, that is the flue gas desulphurisation process and you seem to indicate in paragraph 20 that the Wellman

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Lord process is the front runner as far as you are concerned, where 90 per cent sulphur is removable, although the contra is a generating cost increase of up to 15 per cent. It is on those figures that I would like to ask you another question, because I am not quite clear whether like with like is being compared in paragraph 21. There you say to retrofit one base load coal-fired power station of 2,000 megawatts would cost about £250 million. Have I understood that correctly?

*(*Mr *MacGregor.)* Mr Chairman, I think this is an area in which we have no expertise. We can only observe and study the discussions of others and I think it would be improper for the National Coal Board to take stated positions on this. We can merely report to you the observations that we have made from studying the literature and talking with people in the business, but I think far be it from us to say that this is a solution or these are the numbers and we are going to guarantee that you get them. I think we have to talk to the people who run the boilers before you get any clear indication of how valid these figures are. With regard to the Wellman Lord situation, that is only one of many solutions. It happens to be a British one. It is rather attractive. It may work. It is working in some areas but as I say, it is one of many.

616. These are the figures that you have given to us in your paper, in your evidence, and I now note the qualification that you make about them.

*(*Mr *MacGregor.)* We run no boilers ourselves. Therefore, we have no qualification in this. We have some very keen and assiduously dedicated people like Dr Dainton and his colleague, here, who have been following the state of the art if I may say so, and they are reasonably qualified observers, but I want to give the caveat that we are not going to guarantee how you solve these problems.

617. What I would like to do is ask one of you anyway this: you talk in paragraph 21 of a capital cost of 150 million, which relates to one power station, and you compare that with 400 million, the cost of the total washing of all coal supplies, whereas when we go back to paragraph 14 that we were discussing a few moments ago, you talk to us about the cost of 100 million for the washing of coal. What I am trying to do is understand the way in which you have presented these figures to us.

*(*Mr *MacGregor.)* These are comparabilities.

*(*Mr *Wheatley.)* The answer I think is—if it has a fault in the drafting I apologise, but the fact is that the £100 million refers to the high sulphur coals that we supply to the CEGB which is round about 16 million tonnes. The £400 million refers to washing all the coals supplied to CEGB, which is 67 million tonnes. So that what we are really saying is, we looked at it in two different aspects: the high sulphur coal which probably lends itself to the easiest way of removing sulphur, and that is the £100 million, Chairman; the 67 million tonnes—we would require an investment of about £400 million in new capital, but obviously it would remove more sulphur in total. The purpose of the comparison was really rather what I said before about the relative cost effectiveness for removing a proportion of the CEGB's emissions.

*(*Mr *MacGregor.)* After a great deal of study, it is—I believe I am stating this correctly—the considered opinion of our people that an increase in the intensiveness of washing coal does not unfortunately offer the United Kingdom a cost-effective solution or a dramatic diminution in the sulphur which will be burned in coal.

618. One of the questions I believe I should have asked you earlier is, what scope is there for using only low sulphur content coal in, for example, small power stations or in industry to achieve reductions in SO_2 emissions, and could the use of low sulphur coal avoid the need to retrofit in old private industry—and is enough of the low sulphur coal being produced in this country for these purposes?

*(*Mr *MacGregor.)* As a generality we are not in a position to produce low sulphur coals at highly competitive costs. If industry were forced to use low sulphur coals, I would think they would try to express a preference for imported coals where low sulphurs are offered. We would therefore see that as a threat to our business.

619. I have a last question on this question of desulphurisation where we have just discussed some of the figures available on the cost of controls. In West Germany we were told by power station companies there that once they were faced with the requirement to control emissions by 1988 they have had to develop the technology to reduce costs and increase removal rates beyond the

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required 85 per cent. Before controls were imposed they, like the CEGB and yourselves, had minimised potential costs. Is there any lesson we can draw from that German experience?

(Mr *MacGregor.*) Let us not get mousetrapped into doing what the Germans did. Let us know what we are doing when we embark on this programme to make sure we are using the most cost-effective way of using the coals we have got. Their situation may be different from ours.

620. You think they are laying themselves open to a great deal of trouble and expense, do you?

(Mr *MacGregor.*) Judging by what is going on in Brussels. We suspect they now realise they have disadvantaged themselves and want the rest of us to be in the same boat.

621. Now, if we can come to the next part of your paper, we are concerned there with the sulphur removel during combustion. I do not know whether you are going to tell me again, Mr MacGregor, that you have not done any work on this yourselves and you have relied on what other people have told you, but it does seem to us that some of the methods that you mention here have advantages in that they not only remove SO_2 but they also have beneficial effects as far as NO_x is concerned, and what is more there seems to be an energy saving.

(Mr *MacGregor.*) Well, Mr Chairman, I am a late-comer to the NCB and a great deal of work has gone on and a great deal of dedication is evidenced by the files that I read in attempting to find solutions to problems that face the industry. But I must say, from my vantage point I certainly am attracted to the work that has been done on the combustion systems, especially by the scientists. I have become increasingly aware of the problems that are facing us in the environment with the increasing NO_x/hydrocarbon/ozone complexes, which seem to be features emerging in the scientific study of this field. Any system that we can find which will minimise the NO_x seems to us equally important to the minimisation of SO_2. In fact I am impressed with the debate that goes on in various parts of the world as to what really is the mechanism by which SO_2, NO_x, various hydrocarbons and ozone are interacting to cause some type of change in the atmospheric conditions which may or may not be hostile to various forms of plant life and various forms of fauna in the agriculture systems that are related to this. I believe that perhaps the most important contribution that has been made by the National Coal Board is its preoccupation with fluidised bed combustion, and particularly the pressurised fluidised bed combustion; and, from where I stand, the work that has been done looks quite good and has advanced the situation radically. I believe that the best contribution that the Government can make to the environmental enhancement is to help us speed up with appropriate financial resources the necessary pilot operations and engineering work that will be required to bring this to fruition very quickly. It is the most promising in that it has, in addition to the improvement in the environment in terms not only of SO_2 and NO_x, also the added advantage of having potential for improving the efficiency of the combustion systems, which means that we might end up with environmental enhancement systems that are reasonably self-financing as opposed to those which place yet another burden on our energy costs. I should like to ask Dr Dainton and Mr Wheatley to expand on that.

622. Before they expand on it, may I just say this: most of the evidence we have received so far in this particular field has led us to appreciate, I think, more the significance of NO_x in a lot of the problems that we have seen and encountered, and that the PFBC—if I could use that shorthand—seems to be the most promising technology available to deal with this problem and sulphur at the same time. Having said that, may I pick up your point, Mr MacGregor, where you talked about speeding up the research in this area and bringing commercial plants on stream. Can you tell me what the present timescale is, at the way we are proceeding at the moment, and the extent to which it may be possible to speed it up with the right kind of encouragement from Government?

(Mr. *MacGregor.*) Well, it is difficult to quantify the speed up, but I would say we are proceeding at a pace which would mean that commercial exploitation of the work we are doing, if it turns out to be as satisfactory as we think it will, is at least five to seven years away on large scale applications, and therefore it is absolutely imperative that we spend money not only on telescoping this time-span but also expanding the number and width of the experimentation not just on one system but on a number of systems in other parts of

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the country and the world. Here is a very interesting situation. I believe that the United Kingdom's efforts in this regard may be leading the world. I would hate to see us, having achieved that position, pre-empted because we do not put the effort into it—and I am talking about financial as well as research effort.

623. What king of money are we talking about?

(Mr *MacGregor.)* Our initial programme is a modest one—£25 million—and that is peanuts compared with the problems we face and the opportunities that are presented in this. Mr Edwards has been very active in working on this programme jointly with the CEGB. Perhaps he could say something.

(Mr *Edwards.)* To bring the Committee up to date what we have achieved already is a commercial operation in atmospheric industrial fluidised beds. You can buy one. So that is a big achievement in itself. But that of itself does not sort out the emission problem. What we are working on now is the pressurised fluid bed. We have gone through a major international cooperative exercise which has brought us up to a certain stage and I think that can be summarised as that we can see our way forward—we have not yet achieved it however—to solving the combustion problem. We have not yet taken it forward to the stage of cleaning up the off gases, to run those off gases through a gas turbine, and that gives us the additional efficiency. What we have agreed now with the CEGB is to take up another two years effectively from a date next year in doing two things. One is straightening out all the kinks in the combustion process, and I think we can reasonably say that at the end of two years we will have the solution to that, and it would be very bad luck if we had not. We are also spending that two years in trying to get the technology of gas clean-up to the stage where we could in fact specify and install a gas turbine which would have an odds on chance of succeeding. Now it is impossible at this stage to say whether we will be successful, but if we are, then that could add another five percentage points to the overall efficiency, and that raises 36 per cent efficiency to 41 per cent, say. That is a very very major advance, and it is worth putting in an enormous amount of effort into seeing whether we could achieve it. If you say, "If we spend £50 million instead of £25 million"—which is what we are planning to do—"would you have twice the chance of success or would it halve the period of time?", the probability is No. So I think we have to go through the next stage, roughly on this budget. Some more money would be a help but after that, fairly soon, you get into money which is very much greater than £25 million, because you have to move then to a small but commercially-sized plant, and you are talking then of the order of £100 million or £200 million as an investment either in conversion or in a new purpose-built plant. But we need to move from the next stage of the programme to that commercial stage without any hesitation if we have the evidence at our disposal.

(Mr *Macgregor.)* I am glad my colleague has given you a practical outline of the timetable. I happen to belong to that sort of idealistic school which believes that time and money are, to a certain extent, interchangeable. I believe we can enhance the programme by applying the right resources to speed it up. The biggest problem we face in the combined cycle operation is the cleaning up of the gas stream from the combustion area to eliminate particulate matter principally which would tend to erode the blading of any gas turbine. But this has been done and could be done. It has been done on a small scale and it can be done on a large scale, if we really spend the time, money and effort.

624. The systems we are talking about now reduce the amount of sulphur dioxide and also of NO_x, but because you are burning at lower temperatures you are producing more hydrocarbons—is that right?

(Mr *MacGregor.)* Not necessarily—it depends. Actually any pressurised fluidised bed combustion system gives you better opportunities for control. First of all you can go stoichiometric with additions of oxygen which would tend to control the SO_2 and the NO_x. With regard to the hydrocarbons, I believe that post-combustion in the combined cycle operation would probably convert all of these to at least carbon monoxide, probably carbon dioxide, if we can handle it properly. So we have the opportunities in this for a reasonably environmentally effective system. By the use of calcium compounds or even magnesium compounds you can probably drop 85–95 per cent of the sulphur in the actual combustion zone.

625. You have said two things, Mr MacGregor, first of all that we are ahead of the field but we need a lot more money and we

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could accelerate the research that we are doing into this particular technology. But I do recall reading that the Americans are fairly well advanced in this particular field. It is not a question of our spending more money just to re-invent the wheel, is it?

*(*Mr *MacGregor.)* No. I think, while there is a great deal of effort being spent in some areas in America the opportunities for combining the pieces are greater here, and I think the resources could be made available more readily here. I think Britain has an opportunity that it should not miss. As our work developed much of it is in the public domain, so rest assured that everybody is reading with great care and we will get competition, but we stand at the moment in a good position to exploit these ideas.

626. If you get together a good combustion position is there a market throughout the world?

*(*Mr *MacGregor.)* There is no question about it, it would be be immediately attractive to the people who are being forced to put in stack gas desulphrusation, which is an enormously expensive efficiency-reducing system and one in which the effluent is very difficult to get rid of.

Mr Chapman

627. In your paper, and I refer you to the section on the proposals of the European Commission, you actually finish up in paragraph 30 by saying, and I quote: "Community-wide emission limits applied in the energy sector could well introduce distortions which would militate against the Community ideal of equal competition." I cannot quite understand that. I would have thought if you had a common communal directive which everybody abided by it would make equal competition.

*(*Mr *MacGregor.)* It depends on the structure of coal in each of the Community countries, and there are very widely different utilisations of combustion systems. I would like Mr Edwards to give you a few words on that, because he has studied this extensively.

*(*Mr *Edwards.)* I think there are two things I would like to quote. One is, where do you start from? If you start from a relatively high level of emission, having regard to the industrial activity compared with a low level of emission and it is a percentage reduction you have a built-in advantage. This country has managed to reduce its emissions quite significantly over recent years, and even over the past three or four years quite significantly. There are then quite different aspects of boiler practice. For example, as I understand the drafting of the proposed regulations there is a considerably different level of emission which applies to wet-bottom as distinct from dry-bottom boilers. It happens to be a fact that whereas emissions from dry-bottom boilers are less than wet-bottom boilers in fact in Germany the majority are wet-bottom. We have a tradition in this country of dry-bottom. There are certain built-in quirks, but I am sure these can be sorted out in detailed communications, but the detailed communications do need to take place. So there are two aspects to this problem, one a general and one a particular.

628. Perhaps I could take you now to the concluding remarks at paragraph 28, and again I quote for the record: "The NCB delegate at this symposium, however, noted that"—I find this a very exciting phrase—"the concluding speeches of the politicians and administrators did not reflect the more cautions and less alarmist tenor of the scientific debate which had taken place." I would have thought it would be the other way round from my experience of politicians and scientists. The NERC has asserted to us quite categorically, and surely it is a self-evidence truth, that it is for scientists to present the facts and for decision-makers to act. You are not saying we should leave the decision to scientists?

*(*Dr *Dainton.)* Not at all. The public in the end must make the decision through the political machine. What we are saying is that the evidence that can convince the public they will get value for money is not yet available. We can talk about the cost of a reduction of 30, 50 per cent, whatever, but we cannot tell the public what influence that will have on the environment. We do not know what the outcome will be, and therefore you cannot do a cost benefit analysis.

Chairman

629. If that is the case would it be fair, if we accepted the case, for us then to urge the Government to make available more resources in order to accelerate the experiments and research into the forms of technology that I was discussing with Mr MacGregor a moment ago? We cannot have our cake and eat it.

*(*Mr *MacGregor.)* I answer that because I am inclined to say that we have better control over NO_x in this situation than we

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would have in any other alternative. I progressively am becoming more concerned with the NO_x problem than with the SO_2 problem. The SO_2 problem is manageable. It may take a little time, but it is manageable. There is a growing body of evidence which does not seem to see any co-relation between SO_2 changes and what has happened to the ecosystem, which is very interesting. There are some very interesting reports which I follow from other parts of the world which show negative co-relation between SO_2 emissions and the ecosystem problems. You may well say that is a time lag problem, but in some cases the time lag is quite long and still we have not had any co-relation except the negative co-relation of going in the opposite direction. The one missing piece is what are the interactions between NO_x, hydrocarbons and ozone? My friends in the timber industry in the US are more concerned about the NO_x situation than the SO_2 situation, and I think we have got to therefore look at a more comprehensive solution to the problem than just taking the easy way out by saying, "Get rid of the SO_2." This simplistic approach is appealing, but I do not think we owe it to the public to come up with simple answers to complex problems.

630. Perhaps you should speak to your friends in the motor industry too.

(Mr *MacGregor.)* I agree. I think there is a better co-relation between the ecosystem damage and the increase in motor-cars than in the damage from the increase in combustion of coal. Actually the combustion of coal in recent years in the UK and in other countries has shown a decline in SO_2 emissions.

Mr Chapman

631. Would I be right in saying that the view of the NCB is that if you had to accept the proposals of the European Commission which you talk about in paragraphs 28 to 37 it would in fact leave you at a great disadvantage *vis-a-vis*, for example, nuclear power and low sulphur imported coal from abroad?

(Mr *MacGregor.)* Yes, I think if we follow the line of reasoning in Brussels we would all go nuclear or import our fuels.

632. You said something earlier on and perhaps this is the right place to ask you to elaborate. When we talked about what the Germans are doing you seemed to say they were beginning to regret what they were doing, as recent discussions in Brussels, I think you said, had shown.

(Mr *MacGregor.)* Having been stampeded for political reasons into coming up with very quick, simplistic solutions to problems, the Germans stayed with a high cost operation and they would like the rest of us to be in the same boat.

633. What about Japan? They have been taking pretty tight measures, have they not, and they do not seem to be at a disadvantage economically?

(Mr *MacGregor.)* They have other advantages which we would like to share with them.

634. You do not think there might be a course for Western European countries to follow in Japan's example or do you think the problems are of a totally different nature?

(Mr *MacGregor.)* Japan's example is not actually dealing with stack gas emissions; it is one where they are going fairly heavily to nuclear.

Mr Alexander

635. If I may refer to paragraph 30, "A fixed emission limit will then either be unachievable—except at unreasonable cost—in some member states, or less than the best practicable in others." It appears to me as a simple man that a fixed emission in all member states must be the answer one day.

(Mr *MacGregor.)* Dr Dainton will give you the answer to that, which is not that easy.

(Dr *Dainton.)* We must differentiate between the concept of a reduction of emissions over the whole country agreed across the Commission and on every piece of plant everywhere. We would agree that if the Community as a body wishes to reduce emissions it would be proper to allow each country to find their own way of solving that particular problem of reduction, but how one does it would differ in each particular country. The most cost-effective way in one country will not be the same as in another because of the different balance of energy systems used, for example. We do not like the idea of a fixed emission limit on every size of plant between 50 megawatts and the top, but a national solution to a reduction problem might best be achieved by applying restrictions in some places but not in others and points will be different in different countries.

[Mr Alexander *Contd.*]

(Mr *MacGregor.)* Dr Dainton is talking about the "bubble" situation. In the United Kingdom we, I think, suspect or at least I suspect—Mr Edwards will confirm or deny—that we have a larger number of small individual industrial establishments which burn coal as compared with Germany per unit of GNP. Therefore if you take the simple limit of emissions approach you work very considerable hardship on the small end of our combustion energy system. The Germans may use electricity more extensively than we do.

(Mr *Edwards.)* I think it is fair to say in this country our plants tend to be one extreme or the other, whereas in Germany, for example, they have a lot of combined, basically industrial plants which supply the public sector with electricity and therefore fall in the middle. In this country we have a lot of plants of around 50 to 100 megawatts, and then you go to the central power stations. There is a great deal to be said in terms of the UK experience if you say that emissions have to be controlled for tackling a small number of very large plants rather than, as the letter of the EEC proposal will require, you tackle everything everywhere, including, for example, the 250 large but not very large industrial plants where the cost-effectiveness is very poor. It is better to leave them alone and do a little more with the base load power stations.

(Mr *MacGregor.)* The problem is not just a limit on emissions but control.

Chairman

636. The difficulty is this, surely we have a long tradition in using best possible emissions in terms of pollution going back to the Alkali Inspectorate and the discharge of effluence into rivers and the rest of it. Over the years we have made a great deal of progress by using best possible emissions. That is because basically we have a very good inspectorate who work efficiently and can talk sensibly with industrialists and persuade them into taking the necessary action. The same traditions to not exist on the Continent of Europe and "best possible means" could be interpreted as an escape clause for doing nothing at all and, therefore, they go down the road of fixing norms with which everybody has to comply. There are different attitudes and different approaches to the law in that and I am not sure as members of the Community we can overcome that difference in mental attitude towards laws.

(Mr *Edwards.)* I would suggest, Chairman, that if a reduction has to take place one way is simply to make it incumbent upon the country as a whole to achieve that reduction and then let the government concerned do it in the most effective way possible.

637. So, a limit on the totality of emissions within a country?

(Mr *Edwards.)* Yes.

638. And then you achieve your results within that totality?

(Mr *MacGregor.)* Within the bubble.

(Mr *Edwards.)* The most cost-effective way.

(Mr *MacGregor.)* I think that system is manageable and makes for the most efficient use of the resources we have. As you know, at the famous conference you will notice that the people behind the Iron Curtain refused to accommodate to any limits but they agreed that they would deal with the transboundary situation, they would deal with the situation inside their own house. At the famous 13 nations international environment conference the best that could be obtained from the Eastern Bloc was that they would try to limit their transported environmental effects situation but they are not about to agree to adopt any standards within their individual countries, and that is understandable because they may have some of the same problems we have.

639. Referring to the last sentence in your paragraph 35, where you talk about the problems of Eastern Germany and the USSR, whatever we do in Europe it is not going to have a great deal of effect unless they are prepared to do something. I think that is the burden of your statement. They have recently come out with a statement that they are going to join the 30 per cent Club.

(Mr *Edwards.)* Thirty per cent of what?

(Mr *MacGregor.)* That is the thing I referred to. As Mr Edwards points out, what is 30? I think that here again you have seen that their agreement is only on the transported emissions situation. It has nothing to do with what happens within their countries.

(Mr *Edwards.)* In all fairness, anybody who has been to the Eastern Bloc really can only be overwhelmed by the degree of emissions, very visible emissions, and I am far from clear as to how you actually monitor a 30 per cent reduction of exported emissions. I do not know how you do it.

[Chairman *Contd.*]

*(*Mr *MacGregor.)* As long as they export sulphur dioxide particulate matter rather than radioactive particulate matter, we should be happy.

*(*Mr *Wheatley.)* If I may say so, you touched on it earlier when talking about best practical means but we have a system which has been operating for many years and we tried others. Probably we know more about the emissions we are putting out than many of the other countries, which is very important in this game. We are talking about 1980 as far as 704 is concerned. We have reasonably reliable information on that, but I often wonder even within the Community whether we have that sort of information, but certainly I would raise questions about the East Europeans. It makes a lot of difference what number you say you start with.

640. I suppose we can see that easily within the confines of our own country but it is not taken very well outside, particularly when they seem to blame us as being near, if not at the top, of the league in so far as emissions are concerned in Europe, so, although we may pat ourselves on the back I think they would beat us a bit lower down with a stick given half a chance.

*(*Mr *Wheatley.)* Yes. What I am really saying is that we quote these emission figures, high as they may be in the league table, and it is a question of whether the basis of comparison is always correct.

*(*Mr *MacGregor.)* We are a long way from knowing exactly what the movements are in the atmosphere, the trophosphere or the stratosphere and this subject is just in its infancy as to the facts. You may know the Central Electricity Generating Board and the Coal Board have asked the Royal Society and the Swedish equivalent scientific organisation to see if they can come up with some basis for assessing what our problems are. That is now under way.

641. But even those have been misinterpreted. You are pumping in some £5m between you and the CEGB for further research in Sweden and when we arrived in Sweden the first thing we were assailed with was that this was a bribe in order to get out of our commitments.

*(*Mr *MacGregor.)* I would not take it as a bribe. We asked the Swedish Academy of Sciences to conduct the operation.

642. You are bribing their scientists.

*(*Mr *MacGregor.)* If their scientists are bribable then it serves them bloody well right. I do not think ours are, so we judge other people by our own standards. Unfortunately that may be an improper way to do it. You may have a point there.

Mr Chapman

643. For the record I should say at the least they are saying that this research programme between the Royal Society and the Swedish equivalent and Norwegian academies was to delay Britain taking the inevitable measures it would have to take, so that was their main concern but we tried to disabuse them of that.

*(*Mr *MacGregor.)* I am glad, Mr Chairman, that Mr Chapman is standing up for our honour!

Chairman

644. I am sure we all did when we were there.

*(*Mr *MacGregor.)* Could I add this: the National Coal Board is seriously concerned with the emissions problem and the whole problem in the ecosystem. We live in this country and in this world the same as other people do and we hope our children will enjoy it as much as we have. In these circumstances, we recognise that growing industrialisation has produced some changes in the ecosystem which have to be coped with. We just hope to do that properly and efficiently and not just waste money trying to come up with answers to what I think are still not properly thought-out analyses of the problems with which we have to cope.

*(*Mr *Edwards.)* If I could add to that, in all fairness, displaying our credentials, we had to go through something like 15 years of sorting out the smoke problem and we went into that whole-heartedly on the basis that if we did it properly it would improve the efficiency of combustion of our product and we have absolutely no shadow of doubt that that has been the case.

*(*Mr *MacGregor.)* We have a further innovation which is quite clear and that is that we have an industry that depends on reasonable stability of its future output, as you will understand from the present circumstances, and it would be imprudent to cast further doubts and uncertainty over the plans in the United Kingdom for the use of our fossil fuel materials. If we have the important thing, the cost of the combustion of coals which the systems that are proposed have, then I think we are injecting another element of uncertainty into an industry that

[Chairman *Contd.*]
is already suffering from too much uncertainty and we would find we are driving more and more people to think of the relatively easier solution in terms of the immediate effect on the environment, which is the nuclear solution, which clearly the French have opted for as our major competitor in Europe on energy ideas. They are quite clearly abandoning the use of coal. Certainly they have shown indications of a dramatic decline in their own industry. The reason is, of course, that it is high-cost and takes large subsidies, just as the German and the Belgian and the British one, and they have decided to opt for a different system. I hope that we can try to keep going down the line we are going down and as we come up with ideas, such as the pressurised fluidised bed, we will ultimately end up with a system that takes advantage of the enormous endowment this country has of coal that is capable of being won at a satisfactory economic cost if we just get ourselves round to that point.

*(*Mr *Edwards.)* I think it is fair to say that we all sincerely believe that the present exercise on pressurised fluid bed will reveal in two years' time a system of combustion which will control emissions to an acceptable level, and which will not increase costs. There is the chance that it could considerably reduce costs.

645. Is this not the first time we have mentioned two years?

*(*Mr *Edwards.)* We have got a two year programme starting from a month to be decided in 1985. That is the full period of the programme agreed with CEGB. I think we will be through the combustion part of that exercise earlier and not later, so if you have said two years from today's date, or thereabouts, we will have a combustion system which I think we can all put our name to. So far, at that stage, unless we are very lucky, we will not have demonstrated that we can clean up the gases to get the extra efficiency in the system.

646. And although we may have covered this that time scale is based upon the existing amount of resources you are able to put in and you could reduce that two year period with greater resources?

*(*Mr *MacGregor.)* Unlike Mr Edwards, I think that given money we can speed things up. Let me just suggest that if you have not already done so you should visit the plant down near Cheltenham, at Stoke Orchard, where there has been a great deal of work done on the combustion of coal in the industrial applications as well as in private homes, small space systems. I think that you would be well advised to spend up to a day with Dr Dainton looking at Stoke Orchard because what has already been done on fluidised bed, not the pressurised fluidised bed, but the atmospheric type, represents a very dramatic improvement in combustion systems, and these are now being applied to small industrial applications, and this will quickly lend itself to systems which can be used to remove sulphur during combustion.

647. Thank you for that offer. I am not sure whether we will be able to avail ourselves of it. We are working to a very tight programme and we want to produce our report now with minimum delay. We have reached this far. I am grateful to you for that suggestion. Also, thank you for coming this afternoon. We have found your remarks most helpful

*(*Mr *MacGregor.)* Thank you on behalf of my colleagues. I just want to tell you that I think we can say that we are keenly interested in finding solutions to the problems that face us. In our part in the ecosystem in the UK and Europe. I do hope that we can contribute importantly to improving them and that would be our intention. Thank you.

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MONDAY 9th JULY 1984

Members present:

Sir Hugh Rossi, in the Chair

Mr Richard Alexander
Mr David Alton
Mr Sydney Chapman
Sir Reginald Eyre
Mr Reg Freeson
Mr Robert B Jones
Mr Allan Roberts
Mr Chris Smith
Mr John M Taylor

Supplementary Memorandum by the Department of the Environment: Consideration of the Acid Deposition Issue in the UK

1. Long range transboundary air pollution is by its nature an international problem. It has been clear from an early stage that action by any one country alone would not solve it; and it is an issue which has generally been pursued through international agencies. The UK's own policy considerations and research effort have therefore been closely linked to its contributions to international initiatives and discussion. The Committee may find it helpful to read this note in conjunction with Section VIII of the DOE's main memorandum.

2. Damage related to acute smoke and sulphur dioxide pollution at the local level was well documented in the UK for over a century. Although declines in fish populations of some Norwegian freshwaters had been noted in the first half of this century, the long range dimension began to emerge only in the 1960s, when a Swedish-inspired, European monitoring programme, established in 1947, began to reveal increasing acidity in rain water over Scandinavia and central Europe. The Scandinavians first presented their observations to the OECD in 1969. In 1972 the Swedish Government presented a case study to the UN Conference on the Human Environment in Stockholm which alleged that acidity deposited in their country after long range transport from elsewhere in Europe was damaging their forests, lakes and rivers.

3. The Swedish study received little attention at the Stockholm conference. The UK for its part accepted that there was evidence of effects in fresh waters, but pointed to the need for proper scientific investigation of the causes. There was less general acceptance of the Swedish allegation of forest damage. However, the study emphasised the need for scientific investigation of the extent to which long-range transboundary air pollution might be involved. The OECD, where there was an active group considering air pollution problems, seemed to offer the best forum for such an investigation.

4. In 1972 the OECD Council inaugurated the first international programme of research into acid deposition. Financed by contributions from the 10 participating countries, including the UK, the five year programme was designed to examine the relative contribution of local and distant sources of sulphur compounds in air pollution, and especially in acid precipitation. The UK played a major part, chairing the Steering Group which organised the work and monitored its progress, and helping to develop modelling and analysis techniques including the use of aircraft for sampling pollutants at various stages downwind of the UK. The Group's report established the significance of transboundary movement of pollutants in determining total deposited acidity and showed broadly the contribution of any one country's emissions to deposition of acidity in other countries. For example, the report showed that in 1973 the UK contributed nearly 25 per cent of the total sulphur deposited in Southern Scandinavia (although with an error margin of ±50 per cent).

5. Realisation that this was not a problem confined to Western Europe led to its wider consideration within the ECE. In 1977 an ECE ad hoc group meeting in Geneva (chaired by the UK) produced a proposal for a pan-European programme of monitoring and

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The cost of printing and publishing these Minutes of Evidence is estimated by Her Majesty's Stationery Office at £3,000.

evaluation of sulphur and nitrogen pollutants in the atmosphere. This European Monitoring and Evaluation Programme has been in operation since 1978 and 21 countries (including the UK) participate. These finance their own monitoring stations with central data analysis, etc. being funded mainly from international agencies. It is now proposed to put this funding on a firm basis by contributions from Member States.

6. EMEP is an essential source of information for the Executive Body of the ECE Convention on Long Range Transboundary Air Pollution, signed in 1979. The UK played a full part in the development of this Convention, chairing the special group of experts which drew up proposals for its content. The UK was actively involved in the work of the Interim Executive Body (which took forward the Convention's work of co-operation in research, monitoring and exchange of information and the development of pollution abatement technologies during the period until the Convention came into force in 1983) and is now similarly involved in that of the Executive Body.

7. As well as research carried out under international auspices, a good deal of research has been carried out in the UK since the late 1960s. Organisations principally involved are the Warren Spring Laboratory, the Atomic Energy Research Establishment at Harwell, the NERC, the CEGB and the Meteorological Office. Annex A gives a broad idea of the amount of work carried out by each of them on acid deposition and related topics, (including work done as part of international programmes). DOE, through its research programme, has sponsored work by Warren Spring Laboratory, Harwell and the NERC. One or two key projects are worth specific mention. In 1977, DOE commissioned the NERC Institute of Terrestrial Ecology to conduct a study over 4 years of the effects of acid deposition on forest growth, at a cost of about £500,000. In 1979 a £120,000, four year study was commissioned with Nottingham University to investigate the response of winter wheat to sulphur dioxide. In 1980, DOE sponsored a scientific review of available data on acid deposition in the UK. The Review Group's final report was published last year.

8. Since 1980 there has been a distinct change in perception of the acid deposition problem. In the UK's view, the ECE Convention was the right forum in which to pursue the issue because it brought together all the major countries involved, not just Western Europe, to investigate what was increasingly revealed as a complex problem and thus to provide the basis for decisions on control policies. However the Convention also served to push the issue further into the political limelight. The 1982 Stockholm Conference not only suggested that the effects of acidification might be more serious than had previously been supposed, but demonstrated a growing political will in Western Europe to take action on the issue by placing a commitment on States to work towards a reduction of SO_2 emissions. This commitment was founded on the principle stated in the declaration of the 1972 Stockholm Conference that "States have a responsibility not to damage the environment of other states ... or beyond the limits of national jurisdiction".

9. Any UK policy on acid deposition affects the interest of many Government Departments, (DOE, DEn, DTI, DTp—whose interest lies in the contribution of vehicle emissions to acid rain—Scottish Office, Welsh Office, FCO, Treasury and the Industrial Air Pollution Inspectorate) and also involves NCB, CEGB, CBI and the oil industry. Over the past year a stronger and more positive policy on acid deposition has emerged. Research and development on control technologies has intensified. The latest statement of the UK position is that given to the Multilateral Conference on the Environment in Munich on 25 June 1984.

MUNICH AIR POLLUTION CONFERENCE, 24–27 JUNE 1984

Note by the Department of the Environment

1. This conference, organised by the Federal Republic of Germany (FRG) in association with the United Nations Economic Commissions for Europe (ECE), was attended by 31 member countries of the Commission; virtually all were represented by Ministers for at least part of the time. The ECE Secretariat, the EC Commission, the United Nations

Annex A

RESEARCH ON ACID DEPOSITION

(£k: all figures at outturn prices)

	1972–73	1973–74	1974–75	1975–76	1976–77	1977–78	1978–79	1979–80	1980–81	1981–82	1982–83	1983–84
Organisation												
DOE												
Warren Spring Laboratory	10	44	43	41	20	21	56	92	147	174	200	200
AERE	105	93	118	132	110	95	90	115	115	115	120	220
Other Contractors	—	—	—	—	—	65	69	152	163	163	28	209
NERC	24	*	*	158	191	350	273	372	550	691	860	*
MET OFFICE	*	*	*	*	*	*	825	1026	918	1383	1360	1300
CEGB	*	*	50	83	215	339	596	1462	1155	1035	1401	1146
TOTAL	(139)	(137)	(211)	(414)	(536)	(870)	1909	3219	3048	3561	3969	(3075)

* Figures not available.

Environment Programme, the OECD, and a number of non-governmental environment bodies were also represented. The UK Delegation was led by the Hon William Waldegrave MP, Parliamentary Under Secretary of State, Department of the Environment.

2. Statements of national policy were made by all the delegations present. The United Kingdom's position was that it aimed to secure further substantial reductions of SO_2 and NO_x emissions in future over and above those already achieved (37 per cent since 1970 in the case of SO_2); but that it was not able to enter into a specific commitment for a given percentage by a given date. Broadly similar positions were taken by the United States, Italy and Spain. Ireland, Greece, Portugal and Turkey made clear their view that, because they contribute little to transboundary pollution, no commitment to emission reductions is required of them.

3. The FRG, supported by those countries which had already committed themselves to a reduction of 30 per cent in total annual SO_2 emissions by 1993 or 1995 on the 1980 base, pressed strongly for all countries present to join in such a commitment, and three further western countries (Belgium, Luxembourg, and Liechtenstein) agreed to do so.

4. The USSR, and some other eastern bloc countries, announced that, by 1993, they would seek to make 30 per cent reductions in transboundary fluxes of SO_2 over their western borders. These countries were not, however, prepared to translate these statements into a specific commitment.

5. The Conference resolution, which was adopted by acclamation, embodied a request to the Executive Body of the ECE Convention (at its next meeting in September) to "adopt a proposal for a specific agreement on the reduction of annual national sulphur emissions or their transboundary fluxes by 1993 at latest". Copies of the full resolution will be circulated to the Committee as soon as they are available. Copies of the statements made by Mr Waldegrave, and at an earlier stage on his behalf by Dr Martin Holdgate, are attached at Annexes A and B.

Annex A

Statement by Mr William Waldegrave, Head of the British Delegation, to closing session of the Munich Conference, Wednesday 27 June 1984

The British delegation would like to give a warm welcome to the conclusions of this Conference. A very considerable part of the international community has shown itself capable of making steady progress on the problem of air pollution. We have not allowed the inevitable differences in the particular situations we face, and which must have some impact on national policies, particularly in the short term, to overshadow the more important fact that we are agreed that further progress must be made.

It is this more important area of agreement that I should like to emphasise, so that we do not leave behind us a misleading impression. It was never I fear going to be possible for us all to agree here and now to one single number or date for progress on each main pollutant. Perhaps that has caused a little disappointment but any disappointment should be seen against the very powerful new impetus this Conference has given to the work of the ECE Convention. And in Britain's case we have difficulty with only one thing: immediate adoption, on top of the nearly 20 per cent reduction made since 1980 in SO_2 emissions—of a binding commitment to a 30 per cent drop by 1993. But we are saying "yes" to further substantial SO_2 reductions in a reasonable timescale; "yes" to parallel NO_x reductions; "yes" to a European-wide onslaught on pollutants from motor car exhausts; "yes" to further strengthening of scientific work and monitoring within the ECE Convention and in other contexts; and above all "yes" to an international agreement itself. The initiative and commitment of the Federal Republic, backed by the additional hospitality of the Bavarian Government, has made possible the timely affirmation of new commitments by all of us; we will look back on the Munich Conference as an important step forward, perhaps a turning point in our collective endeavours in the field of clean air.

Annex B

Statement by the United Kingdom Delegation

Mr Chairman, on behalf of my Government, I would like to express our thanks to you and to your Government for inviting us to this meeting—an initiative rightly commended in the communique from the Economic Summit held recently in London. The issues we are to consider are large and complex. Their complexity has been well demonstrated in the paper which your Government, Mr Chairman, circulated to the preparatory meeting of officials in May. My Government, like yours, is concerned with Europe's growing environmental problems—in the forests, the fresh waters and in the deterioration of the stonework of our historic monuments. We wish to see this deterioration halted and, where possible, reversed.

During the past few years we have learned that these problems are not solely due to the direct impact of the phenomenon popularly termed "acid rain". We have learned that we have to be concerned with an ecological situation involving many variables. We have to understand, and respond to, all the components of this situation—the direct action of sulphur dioxide and gaseous oxides of nitrogen: the effects of the ozone formed from chemical reactions between some of these gases and hydrocarbons using the energy of sunlight, and the effects of deposited acidity on waters and soils. We are concerned with the interactions between these factors and climate, forestry and land use practices, and all the other variables that combine to make the science of ecology the demanding study that it is.

My Government's concern is to base action on a proper understanding of the factors that change and damage the environment. That is why we have consistently laid such stress on science. We see no point in making heroic efforts, at great cost, to control one out of many factors unless there is a reasonable expectation that such control will lead to real improvement in the environment.

For this reason, we support initiatives that will enhance our understanding of the European environment. We strongly support the extension of the European Monitoring of Environmental Pollution network, under the ECE Geneva Convention, to document more exactly the concentration of sulphur and nitrogen oxides and the acids in rain over this continent. We are extending our own national network to monitor nitrogen oxides at some 30 sites. We propose to make more measurements of ozone. We have expanded our national research on depositions and effects. Our Government is now spending some £5 million a year in this field. In addition a million a year is being spent on a joint programme between our Royal Society and the National Academies of Science in Norway and Sweden. The public utilities most concerned, have a £50 million programme aimed at developing better control technology to match our national industrial and environmental circumstances. We attach great importance to this last area, because it is our conviction that many of the control systems now available are far from ideal both from environmental and financial stand points. I include in this list the three way catalyst systems available to curb emissions from petrol engined vehicles, the flue gas treatment system to abate nitrogen oxides, and even the more proven flue gas desulphurisation systems. Many are costly, some (like the catalysts) are easily damaged, and some generate solid wastes that are difficult to dispose of in our small and densely populated country. We hope for a new generation of control technology—such as lean-burn car engines, low-nitrogen oxide burners, and fluidised bed furnaces, and we are pressing ahead with all these.

Mr Chairman, we have made some substantial progress in reducing air pollution in the United Kingdom, and we are from time to time disappointed that this is not widely recognised—or worse, that it is often misrepresented. It is a fact that between 1970 and 1983 our national emissions of sulphur dioxide fell by some 37 per cent. Between 1980 and 1983 they have been reduced by 20 per cent. We believe that our share of total European emissions (excluding the Soviet Union) fell from 25 per cent to 11 per cent between 1950 and the present day. Our national emissions of nitrogen oxides have remained virtually constant—or possibly fallen a little in the past 18 years whereas those in certain other countries have risen by up to 50 per cent. Furthermore, these changes are *not* simply a reflection of the recession we have suffered in company with other nations represented here. They have come from positive advances in energy conservation, changes in energy sources, and alterations in the make-up of our industry, with the phasing out of much old, heavy, energy-intensive industrial capacity. We hope to hold on to these gains as our economy picks up—and the fact that our SO_2 emissions fell between 1982 and 1983 while the economy grew by 3.0 per cent is a hopeful sign.

But I do not want to take more time on such details—though I could say a great deal before the record was nearly straight. The fact remains that we accept the need to do more. The United Kingdom is not the largest contributor of pollutants to other countries, but we emit, receive and export more than we would like. We are willing to join in positive and constructive discussions with other Governments with the aim of securing a further reduction not just of national sulphur dioxide emissions but of nitrogen oxides and the vehicle emissions implicated in ozone formation as well. We believe we need to attack all the main pollutants contributing to Europe's environmental problems. I cannot be specific about target dates and percentages—and I have to say bluntly that we do not see our way to joining the "30 per cent Club" in its present form, with its 1995 dateline—but we will be discussing in the European Community and the Executive Body of the Geneva Convention what we can achieve, and by what means. Even though we do not believe it is an effective use of public money to fit flue gas desulphurisation to our relatively modern fossil fuel burning power stations, we are examining a broad mix of measures that will allow us to bring our national total emissions down in a cost effective way.

Mr Chairman, I would like to mention one such positive measure. My Government is impressed by the evidence that ozone, produced by chemical reactions involving vehicle emissions, is likely to be a significant factor in the damage that forests in this country and other European countries are sustaining. We support the positive approach the Commission of the European Communities is taking towards a further tightening of standards for such emissions. We welcome the introduction of unleaded petrol—for which we have campaigned vigorously in Europe—as an early component of this action. We believe that new engine design technology—including the so-called lean-burn approach—offers an attractive pathway towards higher standards. This is the avenue we wish to explore vigorously.

It typifies our national approach. We seek new technologies that achieve pollution abatement as an integral component of design rather than add on costly curative devices to inherently dirty plant. As I said at the outset, we urge all Governments to give high priority to the application of new science and new engineering to the design of industrial systems, power stations and vehicles with low pollution as a basic characteristic. One remit given to my Government from the recent Economic Summit was to work with the other six participants towards better environmental technology, and this is a charge we shall take seriously.

In conclusion, Mr Chairman, I wish to stress that the greater part of the draft resolution circulated in preparation for this Conference is acceptable to us, and that we are optimistic that we can achieve a formula that expresses the concern and commitment for a healthy and beautiful environment that unites us all far more than disagreements on the details of a programme divide us.

We thank you again for your invitation, and will do our utmost to collaborate constructively to make your initiative a success.

MULTILATERAL CONFERENCE ON THE CAUSES AND PREVENTION OF DAMAGE TO FORESTS AND WATERS BY AIR POLLUTION IN EUROPE RESOLUTION OF 27 JUNE 1984

RECITAL

1. *Affirming* that the protection and improvement of the environment, as well as the protection of nature and the rational utilization of its resources in the interests of present

and future generations, is a task of fundamental importance to the well-being of peoples and the economic development of all countries and that many environmental problems can be solved effectively only through close international cooperation;

2. *Recognizing* that international cooperation in the important field of the protection of the environment contributes to the reinforcement of peace and security in Europe and in the world as a whole, which constitutes a significant factor for the preservation of the environment;

3. *Noting with satisfaction* that important steps to strengthen cooperation in the field of environmental protection have been taken in the framework of the ECE, at the Conference for Security and Cooperation in Europe in Helsinki, at the high-level meeting on environmental protection (13th–16th November, 1979) as well as at the Madrid conference.

4. *Deeply concerned* about the damage to forests, soils, waters, ecosystems, crops and vegetation and to materials including historical monuments that has already occurred and is increasing at an alarming rate in a large number of countries;

5. *Conscious* that the consequences of this damage threaten the natural basis of life, result in irreplaceable losses, in particular of historical monuments, and cause significant losses for national economies every year;

6. *Recognizing* that air pollutants, especially sulphur dioxide and nitrogen oxides and their conversion products, are considered singly or in combination with other factors, to be a major cause of existing and increasing damage;

7. *Recognizing* that air pollutants from stationary and mobile sources are frequently transported over great distances and across national borders;

8. *Aware of the need* to better understand the harmful effects of long-range transport of air pollutants and their conversion products by further implementing the Cooperative Programme for the Monitoring and Evaluation of Long-Range Transmission of Air Pollutants in Europe (EMEP);

9. *Recognizing* that, until emission reduction measures become fully effective, additional measures, such as silvicultural measures, liming of water bodies or conservation of historical monuments, will contribute to reducing damage in many countries;

10. *Conscious* that methods for the rational use of energy resources and for energy conservation constitute a substantial contribution to the reduction of air pollution;

11. *Noting* also that new development patterns and appropriate production processes could assist in overcoming the problems of air pollution;

12. *Convinced* that the reduction of emissions at the source using best available and economically feasible technology is a particularly important principle of air quality management;

13. *Convinced* that moreover technologies for emission reduction should be further promoted, improved, developed and exchanged, and research into these technologies should be intensified accordingly;

14. *Recognizing* that numerous methods for substantially reducing air pollution from stationary installations, in particular for reducing sulphur dioxide and nitrogen oxide emissions, are already available;

15. *Recognizing* that effective measures are also available to achieve a drastic reduction of emissions from motor vehicles;

16. *Acknowledging* that the Geneva Convention on Long-Range Transboundary Air Pollution (hereinafter referred to as "the Convention") which was adopted at the environmental meeting at ministerial level (13–16 November 1979) already is a valuable instrument for reducing long-range transboundary air pollution;

17. *Cognizant of the fact* that the Executive Body of the Convention has recognized the need for an effective reduction of annual sulphur dioxide emissions or their transboundary fluxes by 1993/95, using 1980 emission levels as the basis for calculating the reduction;

18. *Noting* that, while in June 1983 nine states declared their readiness to reduce their annual national sulphur emissions or their transboundary fluxes by at least 30% by 1993 at the latest, their number was 11 in March 1984 and as high as 18 in June 1984;

19. *Noting* that for certain countries the annual national emissions or their transboundary fluxes are insignificant in terms of transboundary air pollution;

20. *Conceding* that acid rain is a problem of major concern in North America which requires a joint Canada/USA solution;

21. *Noting* that in North America the Government of Canada has called upon the Government of the United States of America to join in implementing as soon as possible and not later than 1994 reductions of annual sulphur emissions to limit acid deposition in vulnerable areas to no more than 20 kilograms per hectare per year;

22. *Noting* at the same time that the United States government cannot at this time concur in specific additional reductions of sulphur dioxide emissions;

OPERATIVE PARAGRAPHS

1. *Agrees* that international co-operation, within the framework of the work programme of the Executive Body for implementing the Convention, must be intensified for combating damage to forests, soils, water bodies, ecosystems, crops and vegetation and to materials including historical monuments;

2. *Agrees* that national measures to reduce air pollution including long-range transboundary air pollution must be continued and appropriately intensified in order to prevent damage to forests, soils, water bodies, ecosystems, crops and vegetation as well as materials including historic monuments;

3. *Agrees* that continued research into the causes of this damage, into the effects and the transport of air pollutants as well as into control technologies should be considered a matter of priority;

4. *Agrees* that the activities of the "Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP)" should be effectively continued and requests the Executive Body to adopt the draft protocol on financing the co-operative programme to allow its earliest approval by the parties of the Convention.

5. *Recommends* to the contracting parties to the Convention to undertake consultations on comparable methods and criteria for the sampling, analysis and assessment of damage to forests, soils, water bodies, ecosystems, crops and vegetation materials, including historical monuments for a co-operation in the framework of the Executive Body of the Convention with a view to ensuring the ecological surveillance and monitoring of damage to the environment without entailing excessive costs;

6. *Deems it necessary* that the rational and economical use of energy be regarded as a prime objective of energy policy and contributes *inter alia* to the reduction of damage to forests, water bodies, ecosystems, crops and vegetation and materials including historical monuments;

7. *Requests* that all political and economic decision makers do their utmost to promote further energy conservation measures;

8. *Recommends* that increased use be made of the best available technologies which are economically feasible, and which have been demonstrated for manufacturing low polluting fuels, improving combustion processes, and reducing pollutant emissions from stationary or mobile sources and that the further development of such procedures be promoted;

9. *Requests* continuation and expansion of the regular multilateral exchange of experience and know-how within the framework of the Convention and the competent bodies of the ECE relating to emission reduction technology and research as well as increased bilateral co-operation in these fields;

10. *Requests* that close co-ordination be ensured among all competent international organisations in the field of air pollution;

11. *Requests* that, at its second meeting, the Executive Body of the Convention as a matter of highest priority adopts a proposal for a specific agreement on the reduction of annual national sulphur emissions or their transboundary fluxes by 1993 at the latest having regard to the facts that

—a number of countries have committed themselves to implement reductions of national annual sulphur emissions by at least 30 per cent as soon as possible and the latest by 1993, using 1980 emission levels as a basis for the calculation of reduction; a number of other countries announced their readiness and intention to reduce their transboundary fluxes of sulphur emissions by 30% by the same date at the latest;

—the Contracting Parties have recognized the need to decrease effectively the total annual emissions of sulphur compounds or their transboundary fluxes by 1993, using 1980 emission levels as the basis for the calculation.

12. *Deems it necessary* that total annual emissions or transboundary fluxes of nitrogen oxides from stationary and mobile sources be effectively reduced by 1995 considering that a number of countries have committed themselves to implement such reductions at an earlier date;

13. *Recommends* that, to this end, the Executive Body of the Convention at its second meeting take an appropriate decision and include nitrogen oxides in its work programme;

14. *Supports* the efforts of the Executive Body of the Convention to complete as soon as possible the survey of technologies for reducing nitrogen oxide emissions from mobile and stationary sources;

15. *Proposes* that the Executive Body of the Convention initiates activities aiming at the elaboration of long-term strategies, including technical strategies for an optimal reduction of sulphur dioxide and nitrogen oxide emissions or their transboundary fluxes which should be taken into account in setting national emission standards.

16. *Invites* the Executive Body of the Convention to take into account existing research on hydrocarbons as they relate to long-range transboundary air pollution and, subject to the results, decide on further action.

17. *Requests* that, in the framework of the Executive Body for the Convention and in the appropriate bodies of the Economic Commission for Europe, common strategies be developed towards a further reduction of pollutants in exhaust gases of motor vehicles by using the best measures available and economically feasible;

this objective could be reached by

—the use of unleaded petrol,
—improvements in engine technology,
—the use of catalytic converters,
—traffic control measures,
—and other measures;

18. *Requests* that to support the Executive Body of the Convention in executing its task in the field of exchange of information, countries should hold international symposia regularly under the aegis of the UN Economic Commission for Europe to discuss most recent scientific information related to acidification and long-range transboundary air pollution and its policy implications.

NOTE BY DEPARTMENT OF THE ENVIRONMENT ON THE METHODOLOGY FOR ECONOMIC ASSESSMENT OF SO_x ABATEMENT

Introduction

1. The principal forum in which an economic assessment of the costs and benefits of SO_x abatement measures is taking place is the UN Economic Commission for Europe, and specifically within the context of the Convention on Long Range Trans-boundary Air Pollution which came into effect in 1983. Article 7 of the Convention provides for Contracting Parties to "... initiate and co-operate in the conduct of research into ... the economic, social and environmental assessment of alternative measures for attaining environmental objectives including the reduction of trans-boundary air pollution".

Development of the Assessment Methodology

2. The UK has played the leading role in the development of the methodology for such assessments. In 1982 the UN Secretariat prepared a draft methodology paper but this was extensively revised during the course of two meetings of economic experts for which the UK submitted written contributions. The basic methodology framework as now adopted, and reflecting largely the UK approach was accepted by the Executive Body for the Convention at its first session in June 1983.

3. The further remit given to economic experts from signatory countries by the Executive Body was to translate the methodology framework into a practical tool for policy and decision making and the UK has taken active steps to develop a workable assessment technique. A paper (Annex A) was submitted for consideration by economic experts at a meeting in February 1984, and is a statement of how the UK intends to develop these techniques. A further, more detailed, statement of the techniques to be employed, data input and outputs has also been prepared in co-operation with other UK experts. The introductory paragraphs of this statement or model specification are given as Annex B. Annex C is an internal DoE report on the latest meeting of economic experts and includes further details of documents to be considered by the Executive Body and recommendations on future work activities.

4. The practical development of the computerized assessment techniques based on the approved methodology is currently being undertaken by consultants at Cambridge University. Initially, the aim is to get a simplified but realistic version of the system working by September 1984 subject to time and data constraints. Further refinement will be possible as more scientific data becomes available, and this, together with the possibility of considering pollutants other than SO_x, has been incorporated into the specification. The emphasis is however on developing a workable policy and decision aiding tool as soon as possible. (It should also be emphasized that although the technique is being developed within the UN (ECE) context this methodology is also relevant to such problems as evaluating responses to draft EC proposals on SO_2 and NO_x abatement, and the conceptual approach could be applicable in other areas of government policy-making).

Particular Features of the Methodology

5. As the paper given as Annex A points out, the costs of introducing the type of SO_x abatement techniques that are generally considered necessary to combat acid deposition are so large that decisions should not be taken without some evidence of the benefits the measures are likely to bring. However, development of the appropriate aids to informed decision making is difficult. There are various forms of analysis that could be carried out. Cost-effectiveness analysis would compare the efficiency of various pollutant control measures, the criteria for decision making being the amount of pollutant abated per £ spent. Economic impact studies would assess the effect on GDP of introducing abatement measures. For the acid deposition issue, however, the analysis must be of the effect on human welfare in its widest possible sense, therefore the social benefits should be compared to the costs. Social cost-benefit analysis is a well known technique and has been applied in numerous areas of public policy making, but with most environmental problems and acid deposition in particular, where there is so much scientific uncertainty on cause and effect and where judgement or opinion rather than market forces are often the determinants of value, such a technique is not readily applicable.

6. To help overcome the problems of the conventional cost-benefit approach the methodology has been constructed around a 'decision-analysis' approach. The term 'decision-analysis' encompasses a range of evaluaton techniques that are derived from management sciences such as operational research rather than being founded on economic concepts. Of particular value to the acid deposition question is the use of probabilistic analysis as a means of tackling the problem of uncertainty. The final results of the analysis could be framed in terms of the probability of a benefit being achieved rather than a net benefit figure expressed in pounds (£) that would be the result of a conventional cost-benefit analysis. Considerable effort is being put into the way results will be presented. A further feature of the assessment technique is that it is intended to carry out a 'value of research' analysis. This will enable decison-makers to assess the benefit of taking abatement measures now in conditions of uncertainty, and with the risk of being wrong, versus waiting until more definite scientific evidence is available, and thereby possibly incurring more environmental damage. In any event, it is likely that an assessment process as described will highlight the priorities for current and future research effort.

7. The overall intention in the assessment process is to make the analysis as open as possible, to allow decision-makers to be involved at the point where value judgements have to be included and to present the results in a clear and unambiguous form. The assessment technique as described is being applied only by the UK at present although similar work is underway in the United States but it clearly has the potential for application by other signatory countries to the Convention, so that a consistent pan-European assessment could be made.

Environmental Protection, Statistics and Economics Division
Central Directorate on Environmental Protection
Department of the Environment

18 June 1984

Annex A

EFFECTING A COST-BENEFIT ANALYSIS OF THE ACID DEPOSITION PROBLEM

Paper submitted by the Government of the United Kingdom

I. INTRODUCTION

1. The first session of the Executive Body for the Convention on Long-range Transboundary Air Pollution, meeting in June 1983, approved a work plan for the implementation of the Convention. One element of this plan addressed the analysis of costs and benefits of sulphur emission control, and suggested that a working group of experts should prepare detailed arrangements for carrying out such an analysis. In this paper are made detailed recommendations for carrying out this analysis and estimates of the resources that would

be required are provided. The approach to analysis recommended in the ECE report ENV/EB/R8 has been followed.

2. In the next section of this report the purpose of an analysis of this kind is discussed while an argument for a particular type of approach is presented. Section III gives detailed United Kingdom recommendations for how the analysis should be carried out, and in section IV are given an estimate of the resources that will be required to do this.

II. THE PURPOSE OF ANALYSING THE PROBLEM

3. The fact that both the costs of controlling air pollution, and the benefits to be obtained from its control, are very large has led to general agreement that a proper analysis of these costs and benefits must be undertaken. Moreover, since some people argue that the problem of acid deposition is so serious that action must be taken soon, while others argue that any action which is likely to be effective in reducing acid depositions could be extremely expensive and may then fail fully to achieve its objective, it is clear that a proper and detailed analysis is vital.

4. It has already been agreed that the traditional type of cost/benefit analysis is not appropriate for this problem, since there is so much uncertainty surrounding it. Not only are we unsure what the costs would be of achieving any particular emission levels; there is considerable difference of scientific opinion concerning the chain of effects which lead from the emission of sulphur oxides, to the familiar problems of corrosion, health effects on man and animals, and damage to crops, forests, and aquatic ecosystems.

5. Apart from uncertainty, there is, in this problem, considerable room for value judgements. Conventionally, a cost/benefit analysis will ascribe prices to the non-monetary costs and benefits, where possible using market prices. Where markets do not exist, the analyst has to use personal judgement to produce sensible economic models to determine what prices ought to be. In this problem, the evaluation of benefits involves so many quantities of this kind, that considerable judgement will have to be exercised. The analysis will, therefore, have to make all such judgements explicit and allow the users of the analysis the opportunity to vary these judgements, if necessary. This discussion will be taken up again in paragraphs 58 and 59.

6. For both these reasons, it is clear that a cost/benefit analysis of the acid deposition problem cannot result in a clear recommendation of a particular pollution control policy. Output from such an analysis is very likely to result in different appraisals of cost and benefit, dependent on the choice of scientific theory, on the ascriptions of uncertainty, and on the judgements of the relative importance of the different effects, which are included in the model.

7. The analysis should therefore be constructed as a decision aid for policy makers, rather than as an attempt to discover objective truth. Its purpose will be:

(a) To ensure that all available data, and judgements, are tied together consistently;

(b) To make clear which inputs to the model are known facts and which are value judgements;

(c) To allow differences of opinion to be explored by replacing value judgements with others:

(d) To determine on which parts of the problem most research effort is needed to resolve uncertainties.

III. PROPOSED ANALYSIS

A. Overall structure

8. Perhaps the most obvious way to frame an analysis of the acid deposition problem would be to specify some definite control options which might be taken to limit the emission of sulphur and nitrogen oxides, and then to trace the likely effects of these

actions, through emission levels, transport processes, deposition levels, through to the amelioration of effects on aquatic life, crops, buildings and human health. A particular control action could then be described in terms of probability distributions on end effects.

9. International conventions on acid deposition are, however, unlikely to be stated in terms of specific control actions, such as particular methods of limiting sulphur emissions from power stations. The conventions will require participating countries to achieve certain specified emission levels by some specified dates. In order to assess the costs and benefits of such an international agreement, the analysis should take as its starting point proposed emission levels. Given a set of emission levels, defined for a number of different countries (or smaller regions), and over a period of time, the analysis should move in two directions.

10. Firstly, it should represent possible ways of achieving those mission levels, and what the best of these might be. There will be considerable uncertainty, of course, about the costs involved, and even concerning whether a proposed technology will be successful. The analysis must display this uncertainty.

11. Secondly, the analysis must move in the other direction, and by investigating transport processes, deposition mechanisms, and the responses of the environment arrive at a description of the amelioration of the effects of acid rain, taking full account of the uncertainties present, and also of the wide range of effects to which acid rain leads.

12. At this stage of the analysis, any particular set of emission levels will be described in terms of probability distributions on the costs of achieving those levels, on the one hand, and rather more complicated probability distributions on the effects variables, on the other.

B. The modular structure of the analysis

13. It is recommended that the analysis should be framed as a model within an appropriate computer. It should be modular in construction, with each module, as outlined below, modelling one part of the problem. In constructing each module, the analysts will need to choose suitable variables to describe inputs and outputs to the module, to determine how to relate the input to the output variables, to decide how to represent uncertainty, and how to allow the areas of judgement within the module to be changed by a user of the analysis.

C. Time

14. There are many aspects of the acid deposition problem which depend on time. The costs of control will, for example, be composed of initial capital costs, and then annual costs for running the control equipment. Moreover, it is clear that some of the effects produced by sulphur chemistry are cumulative and irreversible, and these effects may need to be studied within the analysis in a time-dependent way. The model must be kept within bounds, however. Thus, it is recommended that initially the model be framed as a description of a steady state, taking average values to represent the time varying aspects. As the analysis proceeds it will become clear to the analysts whether a more sophisticated handling of the time variable is necessary.

D. The iterative nature of analysis

15. This comment about the handling of time raises an important point about an analysis of this kind. The precise form which the analysis should take can only be determined as the analysis proceeds. As modules are constructed, computer programs run, and results are scrutinized, modifications to the formulations will become necessary. In deciding on these modifications, the analysts will need to bear in mind the need for the model to be complex enough to capture all the salient points in the system, but still simple enough to be computable quickly, and to be easily understood. The model will need to be iteratively modified with these goals in mind.

E. Uncertainty

16. Perhaps the most obvious characteristic of the acid rain problem is the uncertainty that exists about many of its aspects. This is of several different types, however. There is scientific uncertainty about the mechanisms involved; sometimes distinct theories lead to rather different conclusions about what is going on. In other areas there is general scientific agreement about the mechanisms, but those mechanisms are themselves framed in terms of probability, rather than certainty. There is, further, considerable economic, and technical uncertainty about the mechanisms that can be employed to limit acid emissions.

17. There are two obvious ways to handle uncertainty; by sensitivity analysis, or by probability distributions describing these uncertainties. Both methods have associated difficulties. If there are a large number of uncertainties, as is certainly the case in this problem, then it is difficult to be sure, in a sensitivity analysis, that crucial combinations of variables, which may lead to subtle sensitivities, have been investigated. Moreover, a simple sensitivity analysis will not lead to a proper understanding of the uncertainty which ought to be held about the value of the output variables.

18. A probabilistic analysis can yield good descriptions of uncertainty, but at the cost of extensive computation. Monte Carlo simulation methods can limit this, but there is still a price to pay in computing time. For a model which is to be used interactively, as should be one of the goals of analysis in this case (see paragraphs 58 and 59 below), this is an important factor to be considered in model construction. Another aspect of probabilistic modelling to be considered carefully is the initial ascriptions of probability. Since many of the uncertainties are not related to frequency data which can be measured, subjective assessments of probability must be used. Here is another judgemental input to the analysis, which must be pointed up in presentations of the analysis; the model must allow its users to vary such judgements to represent their own beliefs.

19. It is recommended that the analysis be constructed so that either a sensitivity analysis, or a full probabilistic analysis, should be possible, on any of the uncertainties, and at the choice of the user.

F. Details of the modules

20. In this section we recommend what the nature of the modules should be in this analysis, and in each case make initial suggestions for input variables, output variables, and how these should be related. We shall not discuss the modelling of uncertainty here, but the reader should bear in mind from our discussion above, that in each module there will need to be some inputs describing uncertainty. We do not expect, moreover, that our recommendations on variables and relationships will remain unchanged as the analysis proceeds, because of the iterative nature of the analysis, as outlined above.

(a) Module 1. Emissions to Controls

21. *Function*: In this module the possible costs of achieving different emission levels will be calculated. The input–output direction is in this case contrary to the direction of physical causality, although it is in the direction of political causality. For each set of emission levels, the model must determine least cost ways of achieving those levels.

22. *Input Variables*: Emission levels of sulphur oxides, per unit time, for each of a set of geographical areas. Since the model may be used either within one country, or internationally, it should be possible for the user to specify the number and type of areas to be used.

23. *Output Variables*: The cost, to each country, of achieving those levels, expressed as an annualized value.

24. *Relationships*: There are several different ways of reducing emissions of sulphur oxides. This module must represent the relationships between cost and achievement for each of these, and determine the cheapest. Since there is considerable uncertainty here,

it will be necessary to do some subtle modelling to give a proper representation of the uncertainty that exists about the costs involved in achieving prescribed emission levels.

(b) Module 2. Emissions to Depositions

25. *Function*: In this module, transport phenomena must be captured. The steady state relationship between SO_x emissions and acid depositions in unit time are to be modelled.

26. *Input Variables*: As in module 1, these will be emission levels of sulphur oxides, per unit time, for each of a set of geographical areas.

27. *Output Variables*: Again for each of a set of geographical areas, deposition levels, expressed in appropriate units, such as sulphur concentration per unit area, per unit time.

28. *Relationships*: There is considerable effort at present, in many different countries, on modelling the transport phenomena which take acid emissions and turn them into acid depositions. This module must include a representation of knowledge here, including both theoretical and empirical studies. If very different relationships are supported by different scientists, then the module must allow the user to select one or another of these relationships, or some suitable probabilistic combination.

(c) Module 3. Depositions to Effects

29. This module will probably need to be split up into the following sub-modules, dealing with the many different effects of acid deposition. The UN–ECE reports ENV/IEB/R.14 to R.17 discuss these effects in some detail. In building the modules described below, the analysts will need to pay great attention to the expert knowledge in these fields which is used in these papers.

(i) *Module 3.1. Aquatic Effects*

30. *Function*: This module's purpose is to capture the likely effect on aquatic life of different levels of annual acid deposition.

31. *Input Variables*: For each geographical area, the deposition levels, as given by the output of module 2.

32. *Output Variables*: The spectrum of damage to aquatic life in a geographical area must be described by appropriate variables. Discussions with experts in this area will lead to sensible descriptors.

33. *Relationships*: Once again, considerable scientific work is being undertaken to assess the relationships between input and output variables. Moreover, there is a view that the effect here is cumulative, and cannot properly be represented, therefore, by a simple annual snapshot, as it were. Some considerable analytical skill will be needed at this point to ensure that the issues of concern are properly modelled.

(ii) *Module 3.2. Crops*

34. *Function*: Here we will model the effects on crops of acid depositions.

35. *Input Variables*: For each geographical area, the deposition levels, as given by the output of module 2.

36. *Output Variables*: Damage to crops is probably best represented by reductions in crop yields, for each geographical area.

37. *Relationships*: The relationship between deposition levels, and yields will be derived from available agricultural modelling studies. Many organizations, including FAO and WHO have studied this area.

(iii) *Module 3.3. Forests and Soils*

38. *Function*: This module will be concerned with the effects of acid rain, and particulate deposition on forests and non-agricultural soils.

39. *Input Variables*: For each geographical area, the deposition levels, as given by the output of module 2.

40. *Output Variables*: The appropriate variables for representing the effects of acidity on forests and soils will be determined by discussion with appropriate experts.

41. *Relationships*: There is considerable dispute at present on the processes causing the observed death of trees, and the change of soil characteristics. This module must be constructed so that opposing theories can be represented within the model structure, and an appropriate one chosen by the model user.

(iv) *Module 3.4. Materials*

42. *Function*: Some commentators argue that the most important effect of acid depositions is the corrosion of metals, and the weathering of buildings. In this module these effects are to be represented.

43. *Input Variables*: For each geographical area, the deposition levels, as given by the output of module 2.

44. *Output Variables*: Again it will be necessary to consult experts in this area; summary measures will be needed, however, to describe the extent of corrosion damage.

45. *Relationships*: Many studies have been carried out to assess the effect of acid deposition on corroding materials. It will be necessary to represent the essence of the results of these studies (with alternatives, if necessary), in this module.

(v) *Module 3.5. Human Health*

46. *Function*: Not the least of the harmful effects of acidity in the atmosphere are the direct effects on human health. In this module all effects of this kind will be represented.

47. *Input Variables*: For each geographical area, the deposition levels, as given by the output of module 2.

48. *Output Variables*: The most obvious summary variables would be mortality (numbers of lives saved each year), and morbidity (number of man-days of illness saved). It may be, however, that more subtle measures of health effects are necessary if the health consequences of acid rain are to be properly represented.

49. *Relationships*: Considerable scientific effort is being devoted to estimating the effects of air pollution on health. Epidemiological studies have not yet been conclusive in establishing a proper relationship here. Once again the advice of experts is necessary to suggest alternatives for selection by the user.

(vi) *Module 3.6. Aesthetics*

50. *Function*: One of the effects of SO_x pollution is a reduction in visibility; another is the change of appearance of acidified lakes. These and other aesthetic effects must be represented in this module.

51. *Input Variables*: For each geographical area, the deposition levels, as given by the output of module 2.

52. *Output Variables*: Visibility will need to be measured by one of the standard variables used in this area, such as the distance that can be seen. Other aspects of aesthetics will also need to be represented, and this may be more difficult. It will be important, however, to use physical variables as surrogates, so that sound scientific theories may be used in the analysis.

53. *Relationships*: Once again, available scientific theories will be needed to relate the input and output variables.

(*d*) *Module 4. Evaluation*

54. *Function*: This will be the most important module in the analysis, we suspect. Its purpose is to take the outputs from module 3, which will be a large number of variables describing the different effects of acid deposition, together with the cost variables from module 1, and to evaluate them for presentation to decision makers. The conventional methods of cost/benefit analysis would, at this stage, seek for prices to translate effect variables into monetary costs. We recommend that the analysis should be framed in a more general way, however, following the prescriptions of multi-attribute value theory. The reason for this is that a direct translation to money would fail to show: (a) the possibility of a non-linear relationship between effects and money; (b) the possibility that the value of the effects may not be additive; and (c) that prices may be a matter of opinion, rather than fact.

55. Multi-attribute value theory has not been used as widely for public policy analysis as has traditional cost/benefit analysis, but, particularly in North America, the method is coming to be used more frequently to analyse public policy issues that involve considerable differences of opinion. The method involves the following steps:

(i) The variables describing the effects of significance to the decision maker are defined, and each alternative being compared is measured with respect to each of these variables. In this case these will be all the output variables from module 3, together with the cost variables from module 1.

(ii) A value function is defined, representing the decision makers judgements about the relative significance of these different variables. This might turn out to be a weighted sum of the effect variables, as would be the case for a traditional cost/benefit analysis; however, this would not necessarily be the case. The value function is determined by a detailed investigation of government preferences, and discussion with policy makers. The analysis must be conducted so that policy makers could insert their own value judgements at this point. As discussed elsewhere, we recommend that the analysis be framed on a computer which will allow for interactive variation of a base case to be carried out by policy analysts.

(iii) The net value of each alternative is then given by applying the value function to the output variables.

56. *Input Variables*: As mentioned above, this module will take as its inputs all the output variables of module 3; it will also take as input the value judgements of the user of the analysis as to the relative importance of the effects variables, expressed in a way to be determined in the course of the analysis. It will also take as input the cost variables from module 1.

57. *Output Variables*: The output of this module will be in the form of profiles of the effects, and costs, of different emission control levels. As we discussed above, we can represent each item by a net benefit value. Alternatively, a less aggregate summary of the effects of different emission control policies could be presented, allowing policy analysts scope to explore the different dimensions of the problem.

58. *Relationships*: We have described the nature of relationships in this module above.

G. Presentation of Results

59. As we have already mentioned, the manner in which the results of this analysis are presented will be crucial to its usefulness. We suggest that the model should be designed to that at least the valuation module, if not the entire analysis could be operated interactively, so that policy makers could explore the implications of different control actions combined with different value judgements sitting at a computer terminal. To this end it will also be of great value to use graphic representations, preferably in colour.

60. A most important early decision of the analysts will be the nature of the computer system on which the analysis will be represented. As we have already argued, it should be possible for users of the analysis to experiment with different scientific theories and value judgements; this will imply the need for fast computing, and, therefore, a powerful

computer. A terminal on line to a large main-frame may be the obvious solution, but it has the drawback of depending on telephone lines and the vagaries of multi-user access. It might be worthwhile investigating the use of the new generation of desk-top mainframes (such as the IBM XT) so that dedicated use and noise-free access could be guaranteed.

H. Value of Research Effort

61. Perhaps one of the most important functions of this analysis will be to identify where most effort needs to be placed in scientific research. The value of information, as defined in decision theory, is, perhaps the most obvious tool in pinpointing such research areas, but we doubt whether it will be at all easy to apply this theory to this problem. We can think of the value of information as the difference between the expected value accruing if the information was available to that which we expect if it is not available. A sensible VOI calculation requires detailed specification of probabilities, and in the presence of more than one uncertainty, the calculations can become very extensive. In this case, where uncertainties proliferate, we fear that such a computation would be well-nigh impossible to effect with any degree of confidence.

62. More straightforward and simple-minded approaches might be more appropriate, such as the identification of those areas where scientific uncertainty gives the most significant possible spread in the effect variables. Such a sensitivity analysis should be carried out to indicate the areas where more detailed research would significantly reduce our uncertainty about the distinctions between policies, and to distinguish these from areas where a reduction in uncertainty will not change conclusions. However it is addressed, the analysis must provide insight into this problem.

IV. RESOURCES REQUIRED

A. Analysis

63. The most expensive resource needed will be the time of analysts. In carrying out this analysis, the following activities will need to be carried out:

(a) Determination of module contents. This will involve extensive discussion with experts concerning what is known about the phenomenon that the module is representing, and a great deal of research into the literature.

(b) Collection of Data. At the same time, analysts will need to collect scientific facts about acid deposition for fitting into the modules.

(c) Construction of model equations. As the analysis proceeds there will be a constant need to revise the equations in the model that are used to relate inputs to outputs.

(d) Specification of computer programs. Finally the analysts will need to specify the nature of the computer code which needs to be written.

64. This kind of task can be done in greater or lesser detail. We estimate, however, that between two and four man-years would be required in order to produce an analysis in which policy makers could have confidence.

B. Computing

65. Two kinds of resource are needed here, namely the programmer and the computer. We have recommended above that a powerful computer should be used for this analysis, and suggest that a "desk-top mainframe", such as the IBM XT, be employed for this work. We estimate that two man-years of programmer effort will be needed.

Annex B

INITIAL SPECIFICATION FOR DECISION ANALYSIS MODEL

INTRODUCTION

The initial basis for this specification is the Methodological Approach and Data Requirements outlined in ENV/EB/R8 and approved by the Executive body at their first session in June 1983. A preliminary probabilistic model was developed from this outline and some examples of the use of the approach were produced and are now included in R9 Annex 1 on the recommendation of the UNECE Cost Benefit Expert Group. Following on from this, the present specification is designed to characterise more fully a detailed model which is described here as a Level 2 complex model. To achieve this, a model, called a Level 1 model, comprising the basic simple framework for the complex model with simple inputs is being built, incorporating sufficient flexibility in its construction to allow the complex inputs and interaction structures required for a successful comprehensive Level 2 complex model.

This specification is therefore for a decision-analysis Level 2 complex model designed to aid decision making in SO_x abatement strategies. The analysis will be in the form of comparing benefits arising from the emissions scenarios developed by the Working Party on Air Pollution Problems with the costs of the necessary controls.

The detailed specification attached is an ideal specification emphasising the complex nature of the problems in each module and some simplification will be required in the model in practice. This is the result of lack of sufficient basic data, dose response functions and other information required to give a complete description of a process. However any simplification will be fully described and will only be undertaken where it is considered that it is still representative of the system and provides a realistic basis for any estimations. Expert opinion will be sought to guide possible simplifications within an area. The UNECE expert groups already exist and would be a useful forum for these discussions.

By the use of this approach a sensible model should be ensured eliminating the use of poor quality information just because it is available unlike previous models, and it represents a considerable methodological advance on the OECD 1981 Study. Areas of large uncertainty can be explicitly recognised and dealt with by decision analytic techniques including sensitivity analysis and contingent analysis.

The model will also have a flexible framework to allow the treatment of energy conservation strategies and pollutants other than SO_2.

Policy Issues

The model is designed to assist with resolving a number of policy issues including:

- (a) The incorporation of a wide range of scientific and subjective opinion within an international forum using decision analysis techniques such as probabilistic analysis to provide:
  - (i) an evaluation of the costs of control strategies to comply with the emission scenarios and the timing of the necessary investments;
  - (ii) evaluation (including magnitude and timescale) and display of the resulting benefits.
- (b) Use of a model on a consistent country by country basis to allow for informed discussions on distributional and equity issues.
- (c) Allowance for discussions on priority for further research and consequences of delay in implementing abatement measures.
- (d) The incorporation of the possibility of examining the effect of other pollutants by having sufficient flexibility in the model.
- (e) Alternative scenarios including energy conservation could be investigated.

Important Features of the Model

The model has certain important features:

- (i) The emission scenarios will be related through the transport and conversion module to the resulting actual effects or benefits relative to the Base Case

Scenario. This will ensure that only those benefits actually produced will be compared with the costs of a particular control scenario.

(ii) Adaptability for general use; thus individual countries can carry out their part of the analysis if necessary under the direction of the decision analyst.

(iii) Explicit treatment of uncertainty through sensitivity analysis and probabilistic techniques.

(iv) Explicit inclusion of value judgements and inclusion of benefits that cannot be quantified in economic terms.

(v) Clear unambiguous presentation to decision makers by the use of alternative forms of presentation of results. This will provide scope to explore the different dimensions of the problem. Benefits will be presented both in terms of a quantitative view of the incidence of effects produced by different emission control levels (a disaggregated approach) and by representation of benefits in monetary terms where possible and contingent valuation for comparison and evaluation of the results.

(vi) The facility for examination of the influence of alternative economic conventions for comparing costs and benefits.

(vii) The maximum involvement of decision makers through the use of an interactive approach.

BASIC OUTLINE OF THE MODEL

The model will have a modular construction, each module describing a particular aspect of the SO_x abatement problem. The modules will interlink, each drawing an output from and providing an input to other modules. The output of most of the modules will be of direct interest and will be able to be displayed by the programme.

The model is designed to operate on two levels. Level 1 is the basic framework of the model illustrated in figure 1 and is currently being developed. This basic framework can at the initial stage have simple inputs to the modules with the need for simplification combined with the need for adequate realism. At a later stage the Level 1 model, which will have a flexible framework, will be developed to a Level 2 model which will have more complex interactions and inputs to the model. The complex inputs can consist of already established models, either run outside the Level 1 model as satellites to the main basic framework, or interfaced to it, providing a range of complex inputs to different modules. As far as possible, already available and proven models, for example dispersion models, will be used.

In constructing each module the analysts have chosen suitable variables to describe inputs and outputs to the module, determined how to relate input to output variables, represent uncertainty, and allow areas of judgement within the module to be changed by a user of the analysis. This is the basis for the detailed specification outlined as follows.

Annex C

UN CONVENTION ON TRANS-BOUNDARY AIR POLLUTION
REPORT OF MEETING

GROUP OF EXPERTS ON COST-BENEFIT ANALYSIS
GENEVA 4–6 JUNE 1984

1. The meeting had been convened to consider the reports resulting from the informal discussions among experts in February and to produce recommendations on further work to the September Executive Body meeting.

2. The meeting was well attended with delegates from 10 western and eastern bloc countries together with representatives from OECD, the International Atomic Energy Agency, the Institute for Applied Systems Analysis (Vienna) and CONCAWE. I was

SIMPLE FRAMEWORK FOR THE MODEL

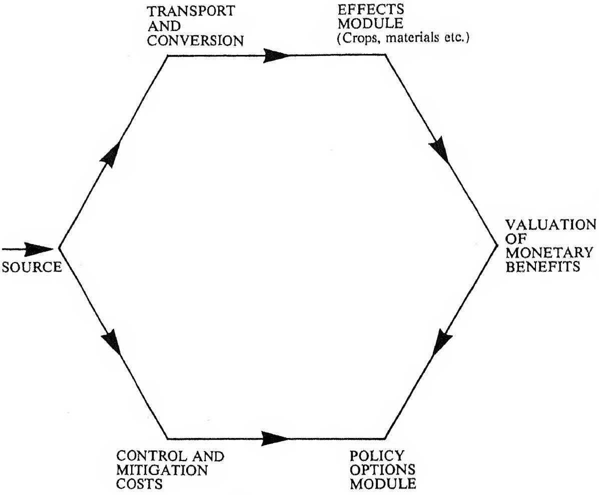
TRANSPORT AND CONVERSION
EFFECTS MODULE (Crops, materials etc.)
VALUATION OF MONETARY BENEFITS
POLICY OPTIONS MODULE
CONTROL AND MITIGATION COSTS
SOURCE

FIGURE 1

elected chairman of the Group and will therefore present a verbal report of the meeting to the Executive Body.

3. The principal papers discussed at the meeting were:

(a) "Techniques for estimating environmental benefits in monetary terms: Recent developments." This was primarily a summary of reports from a recent US conference.

(b) "Examples of the form of output to be obtained from a probabilistic model". This was a paper drafted for the February meeting using data from the CEGB model

(c) "National applications of cost-effectiveness and cost-benefit analysis." This included Dutch, Swedish and US contributions and the report outlining an evaluation framework drafted by Dr Stephen Watson and presented at the February meeting.

(d) "Present status of the UNECE project on cost-benefit analysis and suggestions for future work". The future work areas had been discussed at the February meeting and were now to be revised.

4. The outcome of the meeting was that the Group will present two documents for examination by the Executive Body. The first will be a summary of the national application of cost-benefit analysis. The UK component will now consist of the introductory paragraphs of the recently completed detailed specification of an acid deposition assessment model. The purpose of the document is to demonstrate that significant progress has now been made from defining the methodology to application of models. (The meeting recognised the value of the specification and this will form the basis of further technical discussions.) The other document will be the future work programme, which can be summarised as follows:

(a) Interdisciplinary co-ordination and data requirements.

It was the view of the Group that economic assessment models of SO_x abatement are now feasible but for proper application they need a variety of specific data inputs. A recommendation will be made to the Executive Body that combined economic and scientific expert meetings be held at an early stage so that the data requirements of the analysis can be made known and national research effort and data gathering be directed accordingly.

(b) Signatory countries will be recommended to provide sufficient resources for national application of economic assessments, and that there needs to be co-operation between countries in developing these assessments.

(c) Other forms of economic assessment such as cost-effectiveness and economic impact assessments will also be recommended particularly to gain increased experience in the application of analytical techniques.

5. The report to be presented to the Executive Body will therefore reflect the view that earlier studies of methodology have demonstrated that effective economic appraisals can be undertaken, that the necessary models are now ready (or almost ready) for widespread application, but the scale of the data gathering effort also needs to be considered.

DOE/CDEP/EPSE 2

COSTS OF IMPLEMENTING THE CLEAN AIR ACT 1956: QUERY BY THE ENVIRONMENT SELECT COMMITTEE

1. The Committee has drawn a parallel between current proposals to reduce SO_2 and NO_x emissions and the situation that led to the Clean Air Act 1956. The Committee has asked whether information could be supplied on the cost of implementing that Act, including the cost of grants made by Government, local authority costs of administering and policing the Act, estimates of the costs to private industry of introducing abatement

technology and estimates of costs to householders, and for any evidence of the wider economic costs and benefits.

2. It should be noted that the reference should be to both the 1956 and 1968 Clean Air Acts. (The 1968 Act replaced some of the 1956 Act provisions and enlarged upon others.) It will be appreciated that some of the costs, for example the local authority costs of administering the Acts, can be estimated only on the basis of broad assumptions about the average level of the activity and the average costs incurred. Generally, therefore, the figures can be taken as giving only a rough indication of the scale of costs involved.

Smoke Control	
Total expenditure by householders	£122m
Total local authority element of grant	£135m
Total Government grant	£150m
Industrial Controls	£50m
Local authority administration of Acts	£300m
Giving a total cost over the 26 years from 1958–59 to 1983–84 of	£757m

4. No sound basis exists for assessing the wider economic costs and benefits of the Clean Air Acts. The Beaver report, published in 1954, estimated that air pollution was then costing £250m per year and Sir Hugh Beaver revised this estimate to £350m in 1957. In view of the great improvements that have occurred in air quality over the last 25 years through controls under the Clean Air Acts (assisted by the move to "convenience" fuels), there can be little doubt that damage costs have been substantially reduced. If the Beaver estimate of these costs is accepted, it would seem highly unlikely that the total reduction in damage costs, at current prices, would not greatly exceed the implementation cost as estimated above.

DOE/CDEP
15 June 1984

FURTHER INFORMATION FROM THE DEPARTMENT OF THE ENVIRONMENT ON

Section V. Research on Acid Deposition and its effects, printed page 70, HC446.iii.

1. The Table printed on page 321 indicates the increasing expenditure on research in this field since 1982–83. The programme for 1985–86 is still under consideration and is of course subject to Ministerial approval. There is no doubt, however, that the proposals will call for a further substantial increase in funding in 1985–86, covering two main areas. Firstly it will be necessary to extend the arrangements for monitoring acid deposition in the UK as recommended in the report of the Acid Rain Review Group; the Government is currently waiting on the Group for detailed proposals on the monitoring network, but preliminary estimates suggest that annual costs of about £0.5m might be involved. Secondly, a number of additional research projects have been approved in principle, including work on the effects of low temperatures on the sensitivity of crops and trees to air pollution, on acidification caused by snow melt, on the sources of acidity in soils, and on the buffering capacity of soils. These would be mainly three year projects and would call in total for annual expenditure of about £200m.

2. In addition to the Department of the Environment's research NERC spends some £0.7–0.9m a year and the Meteorological Office some £1.3m a year on relevant research. In addition, the CEGB spends about £1.0–1.5m on acid deposition research and, together with the NCB, has donated £5m over five years to the Royal Society to undertake a collaborative research programme with the Norwegian and Swedish Royal Academies of Science into the acidity of surface waters in Scandinavia.

3. Overall therefore, expenditure on research into acid deposition and its effects currently runs at some £4.5m a year in the UK.

DOE ACID DEPOSITION RESEARCH

Project	Contractor	Contract Status and Duration	Cost in £k					Total cost of contract (£k)
			1982–83	1983–84	1984–85	1985–86	1986–87	
1. Atmospheric measurement and modelling of acid components and precursors	Warren Spring Laboratory	negotiated annually	200	200	312	*	*	
2. Atmospheric chemistry, modelling of photo-oxidants and acid components	AERE, Harwell	negotiated annually	120	220	260	*	*	
3. Effects of sulphur dioxide on crops	University of Nottingham	3 yrs ended Dec. 1982	28	—	—	—	—	121
4. Effects of acid deposition on plants and soils	NERC, Institute of Terrestrial Ecology, Edinburgh	3 yrs started 1983–84	—	189	157	157	10	513
5. Effects of acid deposition on upland soils and streams	Macaulay Institute for Soil Research	5 yrs started 1983–84	—	3	60	57	47	245
6. Effects of acidification on the fauna of lakes and streams in Scotland	DAFS, Freshwater Fisheries Laboratory	5 yrs started 1983–84	—	—	29	29	29	147
7. Chemical inputs from precipitation and their effects on the chemistry of a catchment area	University of Loughborough	5 yrs started 1983–84	—	7	21	21	22	110
8. Combined impact of acid deposition and ozone on vegetation	Imperial College	9 mths ended May 1984	—	10	5	—	—	15
9. Effect of different land management regimes on water acidity, fish stocks and freshwater biota in 5 catchment areas in Wales	Welsh Water Authority/NERC	under negotiation 3 yrs	—	—	109	93	70	272
10. Effects of acidification on freshwater biota in the Rivers Esk and Duddon, Cumbria	North West Water Authority/NERC/Freshwater Biological Assoc.	under negotiation 3 yrs	—	—	50	80	40	170
11. Effects of acid deposition and ozone on trees	Imperial College	under negotiation 3 yrs	—	—	67	58	59	184
12. Effects of acid mists and fogs at altitude, Great Dun Fell, Cumbria	NERC/Univ. of Manchester Institute of Science and Technology/AERE	under negotiation 3 yrs	—	—	66	66	66	198
13. Modelling of acid deposition and photo-oxidants	AERE, Harwell	under negotiation 1 yr	—	—	60	—	—	60
14. Controlled exposure studies of economic materials	Nat. Physical Lab./Building Research Estab.	under negotiation 3 yrs	—	—	50	50	50	150
		TOTAL COST IN EACH FINANCIAL YEAR	348	629	1246	611†	393†	

* Figures not available for these years since the contracts with WSL and Harwell are negotiated annually.

† Sums so far committed: the totals will be increased by sums eventually agreed for work at WSL and Harwell and by further projects which have been approved subject to overall financial constraints. (See text.)

Examination of Witnesses

The HON WILLIAM WALDEGRAVE, a Member of the House, Parliamentary Under-Secretary of State, Department of the Environment, examined. DR M W HOLDGATE, Chief Scientist and Deputy Secretary, Environmental Protection, MR D GRUFFYDD JONES, Under Secretary, Central Directorate of Environmental Protection, and MR P D BURGESS, Principal, Air and Noise Division, Department of the Environment, called in and examined.

Chairman

648. Minister, may I welcome you and thank you also for coming and being willing to give evidence before us this afternoon. I see that you have with you Dr Holdgate and Mr Burgess with whom we had the pleasure of discussing these matters on the 11 June but I do not recognise your third official.

(Mr *Waldegrave.*) Could I introduce Mr Gruffydd Jones who is Under-Secretary, Central Directorate of Environmental Protection, who has been in Munich and Luxembourg with me recently and who will be able to help if we get into that field.

649. That is actually an appropriate point at which to start because when I was asking Dr Holdgate one or two questions on the 11th June the penultimate question that I asked him was this: that we had detected in Sweden some dissatisfaction that we in the United Kingdom had not joined the thirty per cent club and I asked Dr Holdgate how he saw our position in the world with regard to these matters in view of what was being said about us overseas and Dr Holdgate suggested that I might wish to explore these aspects of Government policy when you came before us. Perhaps I might put that question now directly to you, Minister?

(Mr *Waldegrave.*) Perfectly proper passage of that question from official to Minister. If I can start with the Munich Conference: I think that the British delegation initially perhaps got rather a worse press than we thought we deserved on the first day. If I might deal with this most trivial aspect of that first. It was suggested that in some sense there was criticism of my not being able to be there at the beginning because I was answering questions in the House. As a matter of fact a number of other delegates did not have Ministers there at the beginning of the Conference, or Ministers left throughout, so there was no difference in our position than in a number of the others. Our German hosts made it very clear there was no criticism at all from their point of view and we had made it clear several months ahead this difficulty would arise. There was in the press a good deal of speculation that we had had difficult relationships particularly with the Scandinavian countries because of our unwillingness to commit ourselves to joining the 30 per cent club. Obviously I think it is fair to say there was disappointment but I would also emphasise that, and I think my colleagues who were there will confirm this, there was no sense of resentment at all and indeed the Norwegian colleague, whom I think you met when you visited Norway, made a particular point of coming to say to me that she did not feel any sense of resentment and recognised Britain's difficulties. What we said and what I tried to emphasise at the end of the Munich Conference was that, though we were saying no to signing up for 30 per cent sulphur dioxide emission diminution by 1993, we were saying yes to a lot of other things which represented a more positive stance for Britain than she had taken previously. We said yes to the fact that we believe there should be an international agreement on further diminution of sulphur dioxide, NO_x and other pollutants including hydrocarbons. We committed ourselves to further action on SO_2 and on NO_x and we committed ourselves to making necessary contributions to improvements in monitoring under the United Nations Geneva Convention. The next follow-on from Munich, which was a joint German/UN Convention is, of course, the executive body meeting of the Geneva Transboundary Convention in September which I think it is very likely I will attend, though Ministers do not usually attend that body. I think I will attend because I think it is going to be a very important meeting. By the end of the Munich Conference, and if I may say so after the penny had dropped, a number of other countries who had appeared to sign up to the thirty per cent club had done no such thing when you looked at the small print. The USSR did not sign up to the Ottawa 30 per cent club but talked about striving to meet targets for cutting that 30 per cent on transboundary fluxes which are a very different matter. At the end of the Conference I think we found

[Chairman *Contd.*]
ourselves in a group of countries that have difficulties in this area because of the structure of our energy industries but were by no means seen as a block or a recalcitrant rock in the way of progress. We then went on to Luxembourg, if you would like me to deal with that now?

650. Perhaps we could stay with Munich for the time being, if we may. I am grateful to you for explaining to us what was said there. I noticed from both the statement made by Dr Holdgate and the statement made by yourself at the close of the session much emphasis was laid upon the fall in SO_2 emissions from the United Kingdom between 1980 and 1983. Both of you stated in your declarations that these emissions had been reduced by 20 per cent over that particular period and by 37 per cent if one went back to 1970. We are being asked as a country to reduce by 30 per cent from the 1980 base by 1995, if we have achieved 20 per cent since then, since that base already, why is it we cannot now made the additional commitment for 10 per cent in the next 10 years?

(Mr *Waldegrave.*) I think the exact phrase we used was "nearly 20 per cent" because I think we are talking about 17 per cent.

651. If I may correct you, Minister. Dr Holdgate said in terms "reduced by 20 per cent" and I have the text in front of me. You did say, Minister, "nearly 20 per cent". 17 per cent is still—— We do not want to quarrel. The principle of it is near enough 20 per cent between 1980 and 1983, why can we not achieve 10 per cent by 1995?

(Mr *Waldegrave.*) Well, Chairman, of course we could if we chose to undertake the expenditure involved. I think that the way I would put it is this: in this country if we sign a commitment we take it very seriously, we would do it. Our situation I think would be that we would have to adopt flue gas desulphurisation on four of the big coal fired power stations at a cost of about £150 million per power station so one would be talking of around £600 million and it is not quite certain, and I am sure we will want to come back to this, that will be the only cost involved because that will be taking a view I am willing to defend: that we can be relatively optimistic about the stability of the gains we have already made. There are differences of view about this. My Department is relatively optimistic about that. It logically follows you could not quite say it would only cost £600 million, it would only be £400 million, you might have to do more if our predictions about holding those gains that have been made in the past turned out to be over-optimistic. It is a matter we are assessing at the present, the cost and the benefits against the certainty of the gains that would be made at the other end of the problem.

652. You are saying it would cost £600 million to achieve the 30 per cent by 1995, how would that money be spent in your view if we were to go down that route?

(Mr *Waldegrave.*) The only way of being there to meet that commitment would be by flue gas desulphurisation on some of the—up to four maybe—big coal fired power stations and I do not think there would be any other action that could provide us with a reasonable guarantee of achieving that target in the timescale.

653. That is the expenditure, £600 million on flue gas desulphurisation. I want to come later on to technology. We may want to talk to you about pressurised fluid bed combustion and lean burn motorcars which are other options open and might achieve better results than flue gas. Perhaps we could leave that for the time being. The other question I wanted to ask you before I invite other Members of the Committee to follow on is this: we have been talking at the moment of the percentage reductions in SO_2 but during the course of our inquiry NO_x has come to impress itself upon our minds as a pollutant to which equal if not greater attention must be paid. There is nothing in the statement that I have quoted concerning the degree by which NO_x emissions have fallen and although we have the SO_2 equations for that period already the Committee would ——

(Mr Waldegrave.) I have paid close attention to the cross-examination you made of my officials on table 4 of the original evidence on sulphur and the general weakness of the statistical base in this area. I think all I can say is the best evidence, a reasonable view of the best evidence, available to us makes it likely that we have held our NO_x gains about steady over the last 10 years, perhaps there is some evidence there has been something of a decline. If I may say so my own education on these matters has followed that of the Select Committee, in that the importance of NO_x is something which seems to be in common between us, and I think that one of the

[Chairman *Contd.*]

things that the close observers saw as positive in our stance at Munich was we were willing to talk about action on NO_x alongside action on sulphur, which is one of the weaknesses of the 30 per cent club approach in that it only concentrates on one of the pollutants.

Mr Taylor

654. Minister, have you any view on how one should look at the measurement of the damage? You told us in your evidence a moment or two ago very clearly that four of the major coal burning power stations at £150 million each would leave us with a bill of £600 million and maybe some further attendant expenditure as well and I am sure, Minister, you are right. Ought we not to take the broader view and say but what is the value of the damage that we are actually doing to a wider environment, perhaps the environment beyond our own frontiers, and if we cannot measure that damage in pure cash terms we could, nevertheless, take it extremely seriously and be open to the view it might be more deleterious than £600 million. Maybe we are not counting with the same counters on each side of the balance sheet. Should we not be taking a view on the value of the damage?

*(*Mr *Waldegrave.)* I am sure you are right. It is exceedingly difficult, of course, to do this kind of cost benefit analysis in such a diffuse area. There has been some work which I need not draw your attention to because you have considered it: there is the ERL Report, European-wide, then there is the work I think given at the Karlsrühe Conference by Benarie. Now, neither of those bits of work seem to me, with all the confidence of an amateur who was not asked to do the work, all that impressive. One can see the difficulties of making them more impressive, of making them hold weight because the difficulties are immense and the subjective judgments in what, for example cost valuation you put on a slightly increased, slightly decreased rate of emission in building materials is complex. However, the British Government have accepted this is one of the areas, if we are to have rational decision making, where we must do more work. We have taken the lead in the United Nations Transboundary Convention in saying we must do more work on cost benefit analysis. I think you have examined one of my officials on this matter earlier at your previous hearing, so by September we will have a paper which I think we made available to you, which is a draft or is the paper which we put in—It is the paper which we have put in to the UN Convention, so we must strengthen the capacity to take rational decisions in this area.

655. Could I ask another question on control, Chairman? Minister in the course of our evidence—and I am not a scientist but I have been listening to what we have been told—I gather there has been some quite productive research on the trajectories of the pollutants from high stacks and there has been some good work done and fairly precise work done on the circumstances in which long range carriers of these pollutants are achieved—if it is possible—and it seems to me to give some kind of climatic ormeteorological prediction of when the circumstances are upcoming for a long carriage of the plume. Would you and your colleagues be prepared to give a policy instruction to reduce activity when those conditions were upcoming, when long carriers of pollutants were, so to speak, on the cards?

*(*Mr *Waldegrave.)* It is one of the options which, with understandable pride, I think the Meteorological Office put forward: as they improve their skills in predicting the weather they could readily look for ways in which this can benefit us. I think it is an option worth looking at seriously. It has certainly been put forward, both in the paper by the two chaps from the Meteorological Office and also Sir John Mason has put this view forward. I think it is worth considering. I myself would not want to put too much weight on it. It might be part—if one was looking for a menu of things which avoided the huge expenditure, there might be a contribution to be found from that which could be useful. I wonder if Dr Holdgate would like to comment on that?

*(*Dr *Holdgate.)* I do not think so, thank you. As the Minister has said, the Meteorological Office are confident their skills of forecasting are moving to the point where aspects of deposition and sources liable to deposition can be identified and the option of switching to low sulphur fuel or closing down could be considered. It depends on the confidence in 8 the mathematical models.

*(*Mr *Waldegrave.)* It is unfair but politicans and members of the public have less confidence in the Meteorological Office. That is unfair. I believe the statistics show the levels are getting much better.

Mr Alton

656. If I could ask the Minister, when he was in Munich, did he have a chance to discuss with his European colleagues the possibility of co-ordinating together a better research programme to give better value for the research being duplicated throughout the Western Europe? Secondly, did he have a chance also to consider whether the development of emission control technology could be done on a European basis and could he say something about the decision to cut back on research in 1980 and whether he admits now that was, in retrospect, a bad decision because it has put us in a position where we are not able to determine what levels of seriousness we should give to acid deposition and we are not in a position to know what actions we should take in order to tackle those problems?

(Mr *Waldegrave.*) On duplication, I think there is one level where there is room for improvement and one level where I am satisfied things are all right. I am pretty satisfied on the level of interchange between scientists about the work that is being done. The international network of scientists does work extremely swiftly. There are good, I think, conferences. Some would say there are too many conferences—a lot of time has been spent in an aeroplane that could be spent in the laboratory but I am not worried about the spotting of useful work that is being done and its dissemination across frontiers. I think you have a point about whether in terms of initiation of new projects, particularly as we advance towards the order of magnitude increase in cost when you move from basic research to applied research—have people doing things and making things—at that point there is a point for saying coordination is not good enough. Under the Transboundary Convention—which I refer to quite a lot because it is, we believe, the principal international focus and we do not want to invent rival ones, we want to use that—under that, things are getting better steadily and I am advised the situation is beginning to look much more coherent. I accept the implied warning, we must ensure it stays good and not duplicated—except for scientific parallelism where you do want two or three rival projects. I think that side is getting better. It is difficult for a Minister to talk about previous decisions. I am sure there must have been reasons, looking at the priorities at the time, as to why resources were spent as they were. I am told Dr Holdgate struck the table with his fist in 1981 when he was looking at this area and expenditure has been increased since then and we were right so to do.

Mr Roberts

657. Restricting what I have to say to the emissions of sulphur, because we are coming back to No_x in a minute and the problems with acid deposition and acid rain, at the moment we seem to be having a discussion that is a little in code in terms of the Government's position—what the Government may or may not do in the future. That does not surprise me because it seems to me the Government's position has been a bit on and off, and a bit warm, lukewarm, hot and cold, over the last two months or so: the meeting that the Prime Minister had at Chequers and international response and when we have the Department of Energy putting this recent report which seems to imply the Government's position, certainly the Department of Energy's position was they were doubting whether we were contributing to the problem—we were and the Minister has said that the £600 million could do the job easily. We could get rid of the sulphur emissions. We could join the 30 per cent club easily if we thought the expenditure was achievable in terms of the benefits which leads me to suspect the Department of Environment as well as the Department of Energy is doubting the confidence which we show on defoliating forests in Europe and acidification in Scandinavia. Would the Minister clearly state what the Government's position is as regards our contribution to the problem and does he think that we are contributing, does he think we have to wait a lot longer for the outcome of research before he is prepared to agree we need to take action to stop these sulphur emissions or does he think they are a serious factor and something has to be done?

(Mr *Waldegrave.*) There are quite a lot of things in there. I want to put a couple of points. On getting rid of sulphur emissions, this cannot be done by £600 million, getting rid of sulphur emissions could not be done with three or four times that amount. Joining the 30 per cent club could be done with that. What we have to assess is whether in terms of the gains for the areas which are affected both abroad and in this country, that expenditure in that timescale is the best application of the resources. If you look

[Mr Roberts *Contd.*]

back over the previous period and you see the very large gains we have made in sulphur emission—diminution in sulphur—some by good luck, some by good management, some by energy conservation, some by switching in fuel, some by closure of old industries, we have to face the fact we do not see any quick payback from that in terms of improvement. I was taken aside at Munich by a Norwegian journalist who said: "Look, I have a cottage in Norway and 15 years ago, the situation was internationally clean and now 15 years later, thanks to you, it is intolerable", to which I had to reply: "That shows how complex the problem is, because the only thing we have done in that time is cut our sulphur emissions by 37 per cent." That at least shows that the payback is going to be a complex one. If one went to our consumers of electricity and said: "We are going to spend this very large sum of money and we do not really know what it is going to do, whether it is going to resore acidified waters let alone to affect the German forest problem"—where I think the science is beginning to be clear, it is not simply sulphur dioxide in the atmosphere that is the root cause—I am not sure we have much of a story to tell. The British people have as much altruism as anybody else and I am sure they will want to do as much as they can to help other countries. There can be few countries which they feel more towards than the Norwegians. We want to be able to give them a reasonably convincing story as to what improvement we will produce in Norway for what level of expenditure. I do not see yet we can give that assurance in any way that is reasonable. I think you are right to see a hot and cold thing. Everybody wants to do something about the undoubted problems the Scandinavians have, and on the other hand we run up against the block of very great expenditure that is entailed by meeting the easy targets and doubt what meeting these easy targets—in the sense of easy to define—produces. It is a tension which you quite rightly see as pulling in different ways.

Mr Jones

658. The Committee has been struck very forcibly during its visits to Scandinavia and Western Germany by the near unanimity of scientific opinion on the relationship between cause and effect, though not necessarily all stages along the route. We have found almost as much unanimity amongst British scientists who incline to a greater degree of scepticism. Do you think that is simply a reflection of the nationalist aspect on this or is there a good reason why there should be that great gap?

*(*Mr *Waldegrave.)* I am not sure I see a great gap between the sort of views Dr Holdgate gives me about forest damage and those his German colleagues give me. I am sure he is as good a nationalist as any of us. I do not think it affects his position as a scientist. What I see as the gap between us is obviously if you live close to forests, where now I think the latest figures are up to 50 per cent are damaged, you begin to feel something should be done, whereas obviously in one sense it is more difficult to convince British electorate and British consumers that anything should be done if you are not in that immediate domestic situation. I do not see that there is much difference in the sort of scientific advice I am getting, though there is clearly some difference in public perception of the problem. We must be sensitive to that in this country, I think. We must not ignore the strength of feeling abroad. That is why we are saying that more must be done, but we are trying to find ways of doing it that do not load on to our consumers and taxpayers very, very large sums which may not turn out to have been particularly cost-effectively applied; whereas other people's electorates might be forgiven, remembering the concern those electorates felt, I am not sure our electorate would not say "You have just made a nonsense of it, you did not get the science right and spent a lot of our money which has now turned out not to be the best way of applying those resources." I do not mean that I am terrified of being punished by the electorate for it. I am using the electorate in the best sense in trying to explain things to the people.

*(*Dr *Holdgate.)* Chairman, I support the Minister in saying I very much doubt whether the scientists in this country differ from scientists in the Federal Republic of Germany or Scandinavia in not doubting that there have been significant environmental changes causing severe deterioration in many German forests and marked changes in many Scandinavian lakes. I very much doubt if there is much divergence of view over the involvement of air pollutants in one way or another in both phenomena though, as has been said, which pollutant, and the detail does, I think, vary from scientist to scientist here and there. But perhaps one has to remember that scientists live in communities and many of them are very

[Mr Jones *Contd.*]
concerned with the application of their scientific knowledge to help the communities in which they live and which they serve. If you live in Scandinavia or the Federal Republic, you cannot help being impressed as an observer (and scientists are perhaps first and foremost observers of nature) with the phenomena all around you; that may account for a somewhat more immediate, more powerfully voiced commitment by the scientists there than the scientists here for whom these matters have been more academic. I would think that does account for some of the difference.

659. It sounds to me as though the scientists are following the attitude of the general public and, if that is the case, is it not interesting that whereas almost every scientist we met in Europe was in favour of the controls, it is much more limited here? The NERC were in favour of pollution controls. What is your reaction to that?

(Mr *Waldegrave.*) The Royal Commission, of course, asked for one FGD to be undertaken at one of the big power stations to establish the technology. I am not sure I have all that much to add to what Dr Holdgate said. I can easily understand in sociological terms why scientists like any other citizens are willing to take in Scandinavia a slightly different view of the riskiness of the outcome in scientific terms, because it is very pressing for them. I think it was the Nature Conservancy Council, not NERC, who were in favour of the emission controls in their recent report on acid rain.

Chairman

660. I think it was NERC.

(Mr *Waldegrave.*) Has NERC taken a corporate view? Anyway, there is another one as well.

Mr Jones

661. Obviously there is a diversity of opinion. Could I ask whether you have had the opportunity to visit Scandinavia and West Germany and see the damage for yourself and meet some of the people involved in research?

(Mr *Waldegrave.*) I had hoped when I went to Germany recently that I was going to be able to see the forest damage, but for one reason and another, to do with the large number of delegates there were and security problems, it was not possible. Dr Holdgate has visited German forests and there is an outstanding invitation from Norway to which I must respond. If possible, I would like, and be very willing, to undertake those visits. As you may have noticed—you and I have sat on committees elsewhere—I have been relatively busy in recent months on other matters.

662. I was going to come to that. You say "if possible", and I quite understand the difficulties you have been facing. But what sort of priority does this subject have in your own time as a Minister and what sort of time have you been able to devote to the problem in order to try and reconcile these very divergent views?

(Mr *Waldegrave.*) I am finding—with all respect to the duties of local government finance—this the most fascinating part of all my job (I have now offended all the officials not here; perhaps that is all right because they will not read the record) and one to which I attach a high priority is trying to get these matters right. Although there is always a feeling that one can do with more time, the Secretary of State has defined the job to me, because he has delegated the detailed investigation of these subjects to me, by saying, "You must go off to these European councils and international conferences". He has made it perfectly clear that I must put in as much time as necessary to contribute reasonably well on the subject. So I do not feel that it is in any sense a sort of secondary part of my job; I think it is a very important part of it.

663. Finally could I ask you whether you are satisfied with the quality of advice you are getting, not from your own officials, but from various quangos, if I may use the term, such as the Forestry Commission, the National Coal Board, the CEGB and so on?

(Mr *Waldegrave.*) To take three at random! Let me start at the end of that list. I think you visited the laboratories at Leatherhead. I have been travelling around on this subject a good deal and forget where I am. I was very impressed with the presentation made to me there. Though clearly in one sense the CEGB has an institutional view of these matters, in another sense it has a very great vested interest in making the production and consumption of electricity a socially acceptable activity so that I feel that from the CEGB and the scientists working for the CEGB, amongst whom I am advised are some of the very best ecologists in the country——

(Dr *Holdgate.*) Certainly some very capable scientists.

[Mr Jones *Contd.*]

(Mr *Waldegrave.*) I have had a very considerable amount of help from them. I hope when institutional matters intervene they will be honest enough to say what is convenient to them and any aiming off is very easy to do. I have had much less to do with the National Coal Board. As to the Forestry Commission, I do not know if Dr Holdgate would like to talk a little about the Forestry Commission. He has more to do with them than I do. Their role in assessing the extent, if any, of the forest damage problem in this country is obviously very important. We all know about the controversy between the Scottish Friends of the Earth—Mr Carr's report—and the Forestry Commission about whether or not there is extensive damage in the country. I believe Dr Holdgate has been considering having some discussion about that.

(Dr *Holdgate.*) First on the Forestry Commission, I am not a forester. Long ago I was partly a botanist, but I think it would be over-bold of me to say anything other than that I am personally impressed by the knowledge and experience of many of the scientists I have dealt with in the Forestry Commission. The report, for example, by Binns and Redfern on their visit to German forests appears to me to coincide in much of its analysis with what others have said and, indeed, with my own observations, for what they are worth—probably in forestry terms not very much. In this area, of course, we do not solely get advice from the Forestry Commission, though they are the statutory experts in the forestry field, but there are excellent forest botanists also at the National Environment Research Council such as Professor Last who I imagine has also given you evidence. I think the collective knowledge of the specialists with whom we have contact in the Department is sufficient to give not only a picture of where the balance of judgement rests but also something of the variation in that judgement.

Mr Freeson

664. If I might, I will preface the one or two specific questions I had in mind to ask by one which arises from some of the observations we had from the Minister. It points in the direction of policy consideration rather than the detail which makes up most of our exchange. The phrase "pay back" was used several times by the Minister a little earlier on in expressing diffidence or reluctance to come to what he would judge to be hasty policy decisions. One could understand that in a number of ways. If I remember correctly, an organisation called the National Smoke Abatement Society was set up in 1908 and for years campaigned to get smoke cleared from the air. After some decades one or two local authorities began to take individual initiatives—I think Manchester was one—and a number had them in hand at the time of the Great Smog of 1954 when it is guessed (it cannot be more than a guess) 4,000 to 5,000 elderly people died in London alone in four days of filthy smog. Then action was taken. A special committee of inquiry was set up and soon afterwards the Clean Air Act was passed which, amongst other things, involved a great deal of expenditure in subsequent years, sponsored by the then Ministry of Housing and Local Government. Local authorities spent a lot of grant money etc (some, for all I know, are still doing so) in declaring zones under the Act. Was "pay back" a consideration then? I do not recall that more than the most general assessment of that kind was undertaken at the time. Question: if it is believed that sulphur emission is destructive of health and of the environment, even if it has to be measured more accurately and more carefully in the future, why cannot a policy decision—an objective—be made to clear it and then proceed to discuss, to study, to examine how best we go about doing that? That is my first general policy question.

(Mr *Waldegrave.*) Perhaps I can try and respond to that. If I am using payback as a shorthand, all these words are infected with dreadful financial overtones—return, I do not know what word to use; I was trying to find a word to say that the benefits (even "benefits" has a financial meaning) should be commensurate in some sense with the expenditure on the policy. In terms of health, for example, any action in this area would be way outside the normal cost benefit analysis which you would use, for example, in the construction of a bypass road where you have this appalling business—as I am sure Mr Freeson will remember from his own days—of departments having to put a valuation on human life and where you have to do those calculations. We are not in that territory here. On the health side there are certainly problems of acid water supplies dissolving metals and potentially causing health problems—they relate mostly to lead pipes in this country and the attack on that is via the replacement of lead pipes and the treatment in the water

[Mr Freeson *Contd.*]

supply industry of acidified water. The contribution to that of acid rain I think it would be no exaggeration to say would be very, very small indeed. So that you would not achieve a policy decision spending hundreds of millions of pounds in terms of the normal cost benefit analysis on the health side, there is no question of that. The pay back is bound to be much less quantifiable than that because part is bound to be in terms of relations with other countries and in terms of gains for the environment elsewhere and gains for the environment here which are obviously worth getting if we can get them but are not going to be very dramatic. For example, my own family has been very much concerned with the conservation of Wells Cathedral, from the chairmanship of the Friends of which my father has just retired after 14 years. It is perfectly clear that acid in the atmosphere has made a contribution to damaging Wells Cathedral in the past 400 to 500 years, but it is also equally clear that it is not primarily acid in dry or wet deposited form in the ambient atmosphere now, it is what happened in the past. So I think I have to come back again to say that we have made very considerable gains, partly fortuitously, partly as a result of sensible policy decisions on energy use. It is not as if nothing has been happening. We have to be careful as the further we go the more dramatic the cost becomes. We have to be able to show that the further gains are going in the same broad way to be commensurate with the expenditure on them.

665. That conveniently leads me to a more specific question. According to the CEGB who have been before us, we understand that at the end of ten years, and not before that, there would be between five and six per cent additional cost to consumers on the electricity bills if they undertook the 60 per cent reduction recommended under the EEC proposals. I do not know what that translates to offhand in terms of annual capital expenditure. We were given figures and they are on record. Does the Minister really think that such an estimate coming from them, which I presume is the figure or are the figures which the DOE are using as well in these matters, does he really think increasing the cost to consumers of between five to six per cent by the end of ten years is such a tremendous burden that we have to have this reluctance to policy commitment at this stage in the procedure, whatever the specific detailed decision may be?

(Mr *Waldegrave.*) There is very great diffidence about increasing British industrial costs at any time, particularly now. We have made some gains in competitiveness with other countries as a result of gains in productivity recently. We are not thanked when we undertake large increases by ordinary consumers. The subject tends to be sensitive in my constituency when there is any talk of electricity price rises. These are serious. They are not also the only effects. It is the balance between competitiveness of various fuels—which, of course, I am not an expert on, or my department—the comparative cost of coal versus other fuels is dramatically affected within overall difficulties. To undertake additional costs of that kind, even though it sounds not too bad, is a very serious matter and the difficulty, of course, is, as I keep coming back to, that it is not easy to predict the extent of the gains that we would make from it. What would be the extent of the gains we would have predicted if we had been looking at the subject in this committee room in 1970 and we had then committed ourselves to say a 35 per cent cut and we had achieved it as we have? We have been able to do that without charging the consumer anything now. We do not seem to have seen any return at all, at any rate yet, for the environment. I am saying these very considerable sums and additional burdens to industry and the consumer seem to me to need rather tighter connections with the benefits to the environment than we are yet able to demonstrate, if we are to impose them.

666. Many of us said that when buildings got blackened over decades and decades: "Is it really worth cleaning up our chimney stacks and coal burning firesides in our houses and factories?"

(Mr *Waldegrave.*) There was a very, very dramatic impact on public health. You said you could not say how many were killed in the smog of 1952 but everybody knew hundreds and thousands of people were. That was a very dramatic gain for public health.

667. The point is that some people were urging action for decade upon decade before the 4,000 people died, when action was then taken.

(Mr *Waldegrave.*) I accept that. Although we are not saying that we are signing up for a 30 per cent cut by 1993, which is the present date to which the club attaches itself, we are not saying we do not want to

[Mr Freeson *Contd.*]
achieve further diminutions. We will be talking with our partners in September at the executive body of the Geneva convention to see what is reasonably achievable. We are not saying that more should not be done.

Mr Chapman

668. I have three questions to follow on from what Mr Freeson and Mr Alton said. Could I sum up your approach and the Government's approach to this matter. The gist of the view is that you are not prepared to recommend spending hundreds of millions of pounds, and possibly thousands of millions of pounds, reducing sulphur dioxide and nitrogen oxide emissions into our atmosphere until there is at least a greater likelihood or a more certain prediction that there will be a beneficial effect in so doing. Is that really the Government's position?

(Mr *Waldegrave.*) Yes. As an additional rider, to secure additional improvements beyond those we think can be achieved with lesser resources.

669. The second question is, you have said that you feel that it is possible to subscribe to achieve a 30 per cent reduction in sulphur dioxide emissions, as measured from 1980, by 1993, possibly although not necessarily by putting in desulphurisation plants at four large coal-fired power stations. Have you made any assessment of what the actual cost in increased electricity to the consumer would be if you were to achieve and carry out that limited programme?

(Mr *Waldegrave.*) About two or three per cent.

670. That would be over a period of 10 years?

(Mr *Waldegrave.*) That is one certain increase which would be applied.

671. Given the scale of this problem and clearly the different viewpoints as between the top two experts, the United Kingdom government and the Government of the Federal Republic of West Germany, into this matter, recognising it does cross national frontiers, are you satisfied with the amount of government funds that have been allocated to research programmes. I appreciate these have been increased in the last year, I accept the point, although they were cut back in 1980 and also cut back in 1976. Are you satisfied that the government is actually making what some of us might feel a greater commitment, if it is not going to go ahead with a programme of reducing emissions, with the level of funds being made available for research programmes?

(Mr *Waldegrave.*) I am beginning to be satisfied with my Department's contribution. It is easier for us because on the whole we are doing things which cost hundreds of thousands in terms of basic research and monitoring. I thought it very right of the Warren Spring report to criticise the gap in monitoring coverage. We are moving as far as we can to remove that. There is more work to be done on building materials. The areas where we seem to be furthest forward, as one of the Members said, is the very good work regarding the plumes and actually seeing what happens. On the figures we have as to the contributions all around Europe and the percentages in different countries, it seems to be reasonably well based. I seem to sense that the work on the actual chemistry in the atmosphere is pretty good. We are learning more about that. There is a lot more to do on what happens in the soils. The area where I suppose it is most difficult to say whether we are doing enough is in the recalcitrant hypothesis area. You have met Professor Rosenquist. People are seeing things that do not fit in with the general theory and it is difficult to know how much to spend on them. The Hudson Institute said it was all smog in the last decade. If you burn down forests you get a layer of alkaline. If, on the other hand, as I think some of you questioned my officials on last time, if you take away the alkaline burning timber you may have the opposite effect. I think in some of the situations we have to rely on the professional advice to say: "Here is something to follow up with". It may be nothing more than a red herring but we have to find the resources to do it. I am beginning to think that the sort of research we placed funds in is beginning to be all right. It is difficult for me to say what is happening in terms of development of control technologies.

Mr Smith

672. On the scientific evidence that you are presented with, looking at all the effects that you have spoken about on the complexity of the situation, is your conclusion that the emission of SO_2 into the atmosphere from coal-fired power stations does cause

[Mr Smith *Contd.*]
environmental damage in this country and abroad?

(Mr *Waldegrave.*) It must cause some damage. It must contribute to some environmental damage, either now or in the future. I think that is right, yes.

673. You spoke about the reduction in SO_2 emissions overall over the last ten years or so. Would you not think that reduction has come about more as an incidental factor to the transfer to natural gas and the recession rather than from any design and specific effect to reduce emissions?

(Mr *Waldegrave.*) There are two additional factors, one is the energy conservation, which is a matter of real policy commitment and the other is the growth of control technologies. I am thinking of a whole range of other emissions and applications by the Inspectorate. The best practicable means formula does work and things get slowly tightened. You do not allow new things to be put up with the same sort of standards as you would have done a generation ago. You are certainly right, we cannot take credit if this is an argument of ethics, we cannot take credit as if we had caused ourselves the pain of putting in immensely expensive control technology at the beginning. On the other hand, why should we not for once find ourselves with a comparative advantage in this country if by good luck and some good management we have contributed to an easing of the problem. I am sure we would be in the dock if we had had a 37 per cent increase over last decade. It is worth reminding people, and some people who up until recently have not done much about the problem, to belabour people that we have been, purely by good luck, one of those who have been improving. I do not see anything wrong in claiming that.

674. You mention that if we were to go for flue gas desulphurisation in four large coal burning power stations the cost to the consumer of electricity would be roughly two to three per cent over a number of years.

(Mr *Waldegrave.*) I think with the one proviso that my Department's relatively optimistic assumptions about holding the gains we have made turn out to be right otherwise the baseline may move away.

675. I accept that. I wonder if you can relate that to what the average rise in electricity prices has been over the last five years.

(Mr *Waldegrave.*) I have no doubt the question would not have been so pointedly asked unless there had been quite a considerably large figure involved: 50 per cent over the last few years.

676. Finally, and most importantly, returning to the question that all of us have been worrying at over the last half hour: your general approach and that of the Government and of the CEGB seems to be one of we must wait for more concrete evidence before taking action and that is the way also in which the British approach was characterised for us by many of the people we spoke to abroad. How do you answer their subsequent charge that we cannot afford to wait for the four or five more years of research and then the four or five years of development and introduction of technology if it is proven to be necessary, that things are happening so rapidly that action, even if it involved some element of risk, must take place now? How do you answer that charge to our stance?

(Mr *Waldegrave.*) I will try. Perhaps I was rather emollient in my reply to Mr Chapman in accepting his summary about our position. We are saying more action needs to be taken. We are, by taking the credit for the gains that have been made, at the very least laying ourselves open to very considerable difficulty if they were to be reversed. We are signatories to the Geneva Convention, we are committed to substantial further reductions, we are widening the whole matter away from sulphur into NO_x. Our response to the European Commission on motorcar exhausts, which are 30 per cent of NO_x emissions, was positive. There is an area where we are willing to go in to bat and we are committing ourselves to joining in some kind of international agreement. We are saying we will do things and we will secure further gains ahead of scientific certainty. All we are not saying is that being in the position we are with the energy structure we have and all the rest of it that a certain emergency application now of hundreds of millions of pounds would be necessarily right.

Mr Alton: Could I pursue the second question?

Chairman: We have been round the Committee now on general questions, I wonder, because time is going now, whether we could go back to a couple of areas we have not touched on?

Mr Alton

677. I think the Minister in his attempt to give emollient replies might also have given the impression of complacency. Whilst it is fair to say there has been a reduction in NO_x emissions is it not right to say that outside of the Soviet Union this country is the biggest emitter of SO_2 anywhere in Europe?

(Mr *Waldegrave.*) The present position of Italy, Germany and the United Kingdom are not that different but I think it is quite right. As you know very well, the statistics are not all that good. I can assure you there is no complacency in not resolving off the cuff as it were to spend hundreds of millions of pounds of somebody else's money.

Mr Roberts

678. I have a question which comes out of a number of points raised in the Minister's answers and a point Reg Freeson made as well, in relation to, has the Minister considered the cumulative effect of these emissions of sulphur oxide because he talked about a friend who has a cottage somewhere in Scandinavia who said it has been terrible for 15 years and the Minister then said that our emissions have gone down in 15 years. We put this to the Scandinavians and Germans and they talked about the build-up and the effect of continuing emissions and they predicted—the scientists and politicians we met in Germany and Scandinavia—that that cumulative effect would hit Britain and affect our forests and lakes in the way it has affected their's but that our effect will be much later because the amount of sulphur landing in Britain is not as great because we do not get as much imported overseas because of our position *vis-a-vis* the prevailing winds of the Atlantic. Dr Holdgate is shaking his head but it is a thing that frightens me and I would like an authoritative answer. If public opinion in Western Germany and Scandinavia is behind action, and one of the reasons the Minister spoke about not committing this great expenditure is public opinion here is not conditioned for taking the risk with public expenditure not knowing the final outcome, is there not a problem? The only way you are going to get that public opinion is if we educate it or get the same crisis created in this country with the cumulative building up as has happened in Western Europe? Should we not be learning from what has happened in Western Europe and responding before we get the damage and acidification?

(Mr *Waldegrave.*) There was a famous member in the party who once said there were people going up and down the country stirring up apathy. I would not want to think that is the Government's stance on this matter. Can I perhaps correct myself? There is always a danger in using anecdotes because they may not be exact. The use of my anecdote about the Norwegian person with the cottage was simply to illustrate that it is at least more complex than a linear one to one relationship; we will not see an immediate gain on a linear basis between the cutting of our emissions and an improvement in the environment in Norway or anywhere else. Equally when I talk about convincing people here of course I suppose one could launch a great campaign to try and persuade people but it seems to me the great danger of an environmental policy is to make, in this or any other area, a very big expenditure mistake because that affects commitment to the policy subsequently all over the place. That is why if we can seek to make further gains that do not commit us to a very huge expenditure it seems to be prudent to try and find them if we can.

(Dr *Holdgate.*) Scientifically I think most people would accept the very real probability that there is a time lag in the passage through so complex a thing as an environmental system of a deposition into the soil or catchment. I shook my head over one or two points. One was that we might encounter deposition of acidification later than others whereas I think there is good evidence that in the period of the Industrial Revolution there were lakes in Southern Scotland that were acidified between 1850 and 1890 and there is no doubt some industrial areas of the Central Pennines were acutely acidified where forestry was impossible in that area. So, to a degree, we have had demonstrations of what acute industrial pollution can do. In terms of deposition per hectare in the areas where it is highest in the United Kingdom we are receiving as much as in the other countries affected so I do not think the hypothesis that it is stalking up on us is necessarily valid.

Chairman

679. Minister, I think in a sense it answers a question you put to the Committee a little earlier. You did say to the Committee: "How is it possible to go to electricity consumers and suggest to them that their bills

[Chairman *Contd.*]

may have to go up by two, three or even 10 per cent? What can we say that they will get in return?" I think Dr Holdgate has just given an indication because we have taken evidence which shows that since the short-range pollutants have reduced in quantity over the past few years there has been a reversal in the Pennines. Whereas previously it was impossible to grow trees there now it is beginning to be possible. We have also seen in Scotland that because of the long range transportation of pollutants a number of lochs there are at greater risk than they have ever been before and if action is not taken, difficulties may arise. We have also, or some of the Members of the Committee, have seen damage in the Lake District trees which bear a very striking relationship to the damage that we saw in the Black Forest, although our Forestry Commission, in their present state of knowledge, are not prepared to say that that damage now in the Lake District is due actually to pollutants. We have also taken evidence to show that acidity in the atmosphere—dry or wet deposition—has a corrosive effect on buildings. Many of our historic buildings will require very vast sums of money to correct damage caused and if one adds all that up together, one may have to consider that some remedial action will have to be taken and the equation, I am afraid, is something that the Government will have to work out for itself and I hope, as a result of our Inquiry—and we have been able to spend some three months of our attention devoted to this whereas you, Minister, have other things to do—perhaps we will be of some help to you to arrive at a conclusion ultimately. I have given an answer to a question that you asked us. May I ask a question: if it is decided to spend money, obviously money will wish to be spent in the most effective way, you have indicated some £600 million in flue gas desulphurisation. When we spoke to Mr Ian MacGregor of the National Coal Board, he was very very enthusiastic with the installation in our power stations of pressurised fluidised bed combustion systems, and the effect of which, we have had evidence from other sources, reduces the sulphur emissions by up to 90 per cent at the same time reduces considerably the emissions of NO_x and what is more, can be achieved at an economy of some 13 per cent in fuel use, in energy use which seems to amount to an interesting package indeed. Now, Mr MacGregor told us that he believed that these forms of combustion will be ready for commercial use in two years time given the present rate of research and given more money that time scale can be even further reduced. Given all the discussions that we have been having this afternoon, would that not seem to indicate an area on which the Government could make a determined thrust?

(Mr *Waldegrave.*) Could I comment, there were one or two points, Chairman? Could I comment on those?

680. Of course.

(Mr *Waldegrave.*) I have no doubt the Select Committee will be very helpful to us. I mean that genuinely. It has been very helpful to me, even reading the reports of your evidence and so forth because you have gathered together in one place, as it were, most of the knowledge. The only thing I would say about the points you made is we had to be sure we added into the cost side things that are on all fours with each other. It may be things done to the Wells Cathedral were caused by coal fired power stations. Certainly the Pennines damage was localised old fashioned smog which has been reversed, certainly that was there and can be reversed. I am not quite sure the Scottish lakes are long range transportation, certainly some of the Galloway lakes seem to be local acidification, still nobody doubts there are gases about in the environment. The fluidised bed is the philosopher's stone, my only hesitation—and it derives not from my official advice or official position but it derives from the fact I used to work in the power engineering industry—I seem to remember people saying always optimistic things about fluidised beds, it always seems to be round the corner. I very much hope Mr MacGregor is right and that the beauty of the system is undoubtedly to cause —— You then get on to what you would do with it. Part of our difficulty is we will not be able to forget coal fired power stations in the near future. As I understand it, unlike the low-NO_x burners, this is not an option you can retrofit into a power station, this is a whole different system, which is why, understandably, with the low-NO_x burners, if things could be retrofitted into many power stations, why that should be pursued vigorously. I am absolutely with you, both in your hopes of pressurised fluidised beds and hopes we are putting enough into it.

681. I know this is outside your field but Mr MacGregor's enthusiasm stems from the not unnatural desire on his part to sell coal

[Chairman *Contd.*]

and if he can show coal to be sold without being a pollutant, there may be less desire to have atomic power in fueling power stations. He would like us to go down the road where anybody would be happy and he could sell his coal. Perhaps you might like to speak to your Department and your colleagues in the Department of Trade and Industry to see whether this aspect of the matter could not be pursued with far greater vigour?

(Mr *Waldegrave.*) We are closely in touch with them and I have heard from the CEGB who are interested in this. I have had a presentation on pressurised fluidised beds. We note what you have said.

682. The other matter we ought to touch on, because it relates to control and the pressure the United Kingdom Government will be under from Europe to have norms, we by contrast have always followed, in so far as pollution is concerned and alkali inspectorate and water etc., "the best practicable means", that is the traditional British way of dealing with these problems. How can we reconcile our approach with the draft directorates being laid down in Europe?

(Mr *Waldegrave.*) In terms of the argument on this, I have come to the conclusion, having done one or two council negotiations on this matter that it is very often that most unsatisfactory thing of all, an argument of pure principle and that in reality if you forget about the principle and look at what happens in the different countries, you do not end up with different systems. That is why we were able to accept the framework directive on emissions for industrial plant recently because we were united with our colleagues in where we wanted to get to broadly and we were able to find ways of reconciling our system based on not having mandatory emission limits but BPM with an approach based more usually on mandatory emission limits. I do not see that as being necessarily the block it ought to be, if you look at the logic, but luckily we seem to be more sensible than that and we find ways of squaring this particular circle so we end up in the right place. I think they understand and respect our long history in this area and they know when we say we will achieve the same outcome as they achieve by theirs, they tend to believe us.

683. There is also the belief, and perhaps it is because the continental attitude is somewhat different, that when imposing controls then it is more difficult to achieve positive and longer term results by relying on everyone to use "best possible means" rather than by imposing fixed limits upon them. Certainly that seems to be the view of scientists in most of the other countries we have discussed these matters with and also the view of NRC who seem to indicate to us they would like us to recommend that emission controls be introduced in this country.

(Mr *Waldegrave.*) I am not sure, again, there is all that much difference in where we get to. I note, for example, Dr Leslie Reed, the Chief Inspector, said in his annual report last year or the year before—1981—he was inclined to think if there were coal fired power stations being built, he would want to insist large developed sulphur emission controls were achievable within BPM. So he, as it were, was giving notice of the sort of tightening that you would do in other countries by means of setting some years ahead a tigher emission standard. So I am not sure that we necessarily get to a very different position. It all depends how rigorously you run your BPM policy. If it is a proper tightening noose, where you really press as technology advances, as it does in this area, you can find yourself advancing beyond the emission controls at a time when the emission controls may well have become a protection for industry. They may well be sheltering behind them and saying "You passed this law and cannot change it now". As long as you take the progress of BPM seriously and have a pretty rigorous definition of what "practicable means" are, I am not sure that the strengths of our approach do not meet and more than balance the weaknesses; though since it is very characteristically a British way of doing things, it is often difficult to explain to our European partners how it works and we are only now getting this established in Europe, I think, as the understanding is increasingly there. One could easily have a system like ours which was full of loopholes, but the more they examine our system the more they find it is not actually like that.

Mr Freeson

684. It also does tend to undue indecisiveness on policy matters. May I go back to your point when you mention ——

(Mr *Waldegrave.*) If I can come in there, I would not accept that, for the reasons I have just given.

[Mr Freeson *Contd.*]

685. That is a matter of opinion as one sees life politically and otherwise. To illustrate the point rather more vigorously, may I go back to your questions regarding fluidised bed combustion? When we had the NCB they were telling us it would be ready for commercial use in two years or earlier if more money were available. When the CEGB were questioned about this on 21 May I asked whether it would be possible to have such a system introduced within the ten-year programme period we are generally referring to in these matters, and the answer I got from Dr Chester was, "I have to say 'within it' might be misleading. I think at the end of it or within five years following it, that is, within fifteen years from now". Today we get an answer from the Minister which is even more uncertain: What I am trying to illustrate here is a lack of commitment somewhere to find out, to say: This is one of the options of achieving what we would like to do. Let us get down to it jointly between the Department of Energy, the Department of the Environment, the NCB and other people—not passing pieces of paper or making visits to one another—establish what the truth of that particular proposal is. Is it two years or less if money is available? Is it fifteen years? Or is it some uncertain period of time? I am using this as a way of illustration, because there are other control methods which could be introduced if there were commitment—legislative and policy commitment—without which, would it not be correct to say, we could carry on year after year with the kind of uncertainties that have clearly come out on this particular technology on which we have exchanged questions and answers in this Committee up until now?

(Mr *Waldegrave.*) Can I say on the fluidised bed, very frustrating though it may be for people like me—perhaps even for people like the Committee—you cannot have certainty as to when engineering problems are going to be solved. One of the really disastrous habits of this country since the war has been what you might call the crash programme syndrome—that is one of my favourite subjects but I will not go into it—whereby we have thought all the problems of, for example, nuclear power stations were soluble quickly if you put a tenth of all the engineers in the country to work on them and spent more or less unlimited sums of money; they were not. All the commercial pressures, as you rightly said, run in favour of doing that; if they could get it on stream they would. I believe there are some engineering problems still to be solved. I believe also they are getting nearer and nearer to being solved. There is no lack of commitment or lack of co-ordination in our knowledge of that. There is a Babcock 300 megawatt fluidised bed under construction in Germany. But the immediate relevance of the fluidised bed is not all that great, certainly not in terms of meeting the 30 per cent, because here we are talking about the construction of new plant. It is certainly the case that small fluidised beds will be relevant to other industrial emissions. In terms of meeting a short-term programme, say, on a commitment of 30 per cent of SO_2 the fluidised bed is not all that relevant. The technology of the fluidised bed of course is well understood. That is why we are able to give relatively certain figures of what the cost would be. We know from the plan and elsewhere what is the cost because it is done.

686. I think with respect, though what the Minister has said was of interest, it missed the central point I was making by that illustration. We are not saying whether it should be two years, six months or ten years, but when different people involved in this field under government guidance and direction give such wide variations and we get such a diffuse answer from the Minister, with respect, one does expect to get something better. One should expect to have some kind of assessment in government of just what the realities are. It may be twenty years for all I know, but somewhere it is possible surely to get this co-ordination?

(Mr *Waldegrave.*) There may be questions to which there is no single answer. There may be different views depending on how you assess the problems.

Chairman

687. Minister, we have been cross-examining you solidly since 4.30 and we have to thank you very much for handling the questions in the way you have done. This is the last of the sessions in which we are taking oral evidence and, as you pointed out yourself, we have collated and we hope brought together into one source a great deal of evidence from a variety of disparate sources which was diffuse before. We hope that that will be of help. Certainly during the course of our inquiry our own ideas have become much clearer and much sharper as no doubt the drift of our questions has indicated to you. We are not quite sure how helpful the Government may or may

[Chairman *Contd.*]
not find our report; that is another matter entirely. At this moment may I thank you and also your officials who have supplied us in turn with papers and with evidence for which we are more than grateful. Thank you very much.

(Mr *Waldegrave.*) I think we are all grateful for the work the Committee has done. I apologise to Mr Freeson if my replies are diffuse. It is in some respects a diffuse subject.

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